Road and Landslide Sediment Source Investigation
And Sediment Reduction Plan
For the Scotts Creek Watershed
Santa Cruz County, California

Prepared for

The Scotts Creek Watershed Council
Davenport, California

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Aerial Photograph Set ~ Coordinated and paid for by SCWC larger landowners Lockheed-Martin, RMC Pacific Materials, California State Polytechnic University, and Big Creek Lumber Company.

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PROJECT INTRODUCTION

The Scotts Creek Watershed(herein after called SCWC), funded by an SB 271 grant received from the Department of Fish and Game, contracted with several parties to study possible sediment sources in the Scotts Creek watershed. The purpose of this study was to discover what natural and manmade elements in the landscape were contributing to salmonid habitat degradation through erosion and landslides. Landslides are common, natural occurring events in the California Coast ranges, and can benefit fish in many ways by increasing in-creek habitat structures, hydrologic roughness with boulders and rocks, and augmenting spawning gravels. Slides, however, also increase fine sediment in streams which can smother redds(egg nests) and result in high or complete egg and alevin mortality. Abundance of fine sediment in the stream system can also have strong negative affects on the success of macro invertebrates that are the food source for salmonids. For this reason, knowledge of the source of sediment in the watershed would allow identification of solutions for its reduction.

Specific areas chosen to study were existing roads, slides, and obvious creek sediment sources. The project consisted of four parts. First, an initial evaluation of the entire watershed based on previously gathered data such as aerial photograph sets and maps. The second step was the performance of on the ground surveys, mappings and evaluations of sites. Third, with the problems identified, a treatment was recommended for each site. Finally, priority sites were determined based on several criteria. The result of this study is a list of problem sites with recommendations for reducing their sediment input in the riparian corridors.

GENERAL WATERSHED INFORMATION

The Scotts Creek Watershed is a 20,000-acre coastal watershed approximately 14 miles north of Santa Cruz (*Figure 1*). This watershed terminates at the Pacific Ocean in the Monterey Bay National Marine Sanctuary. The Scotts Creek watershed is home to over 600 native plant species and subspecies, which together comprise 10% of California's fauna. It is also home to the endangered coho salmon, , california redlegged frog, the snowy plover, the tidewater goby and recently listed steelhead trout. Scotts Creek has an orientation somewhat unusual in the central coast, in that the stream runs parallel to the coast for approximately 5 miles before turning inland. There are numerous tributaries to Scotts Creek. Starting from the estuary and moving upstream, they are Queseria Creek, Archibald Creek, Winter Creek, Little Creek, Big Creek, and Mill Creek. All of these except for Archibald Creek and Winter Creek are perennial streams which support anadromous fish (*Figure 2*). A network of seasonal, unnamed creeks are present throughout the watershed system.

Scotts Creek Watershed General Location

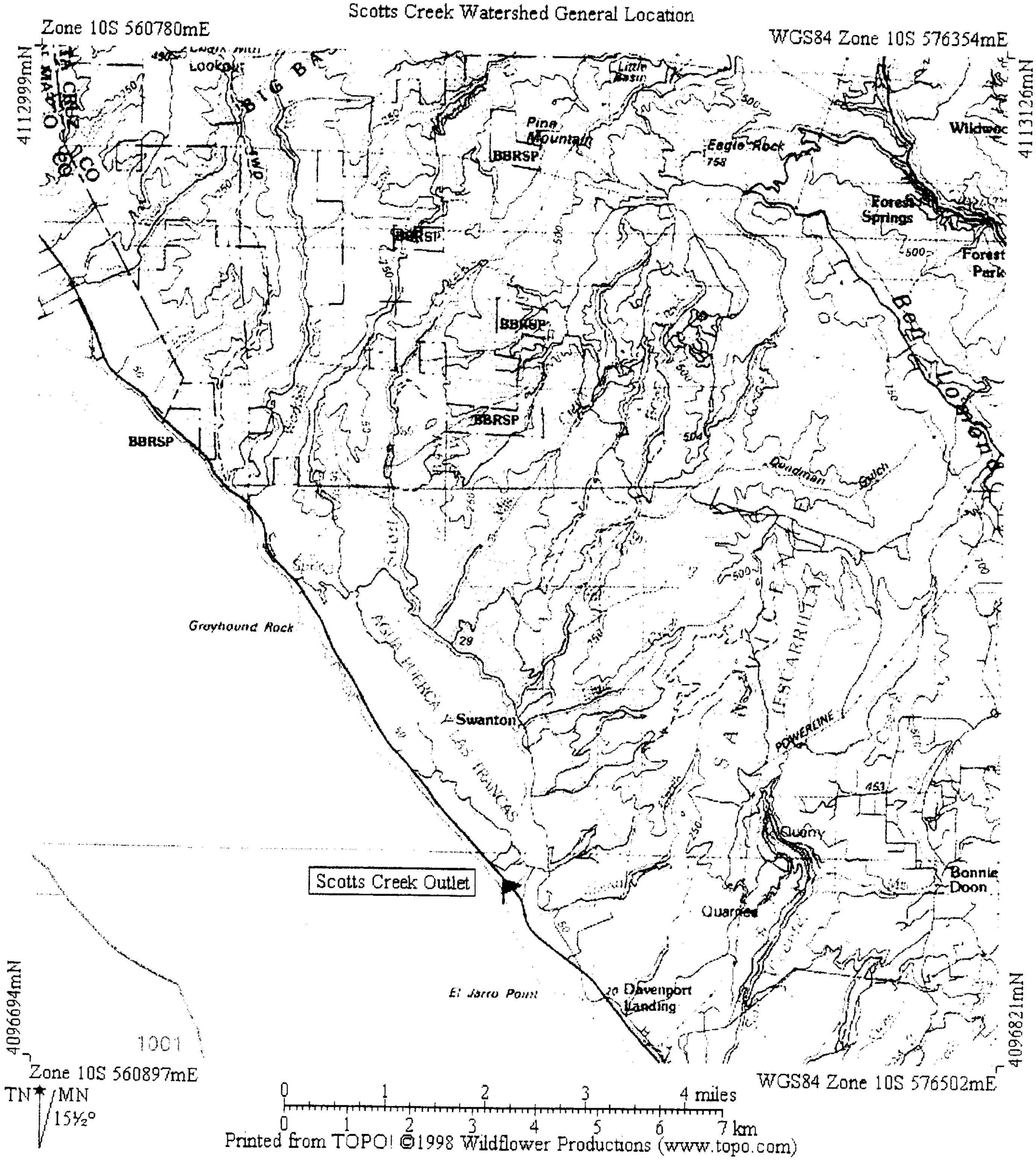
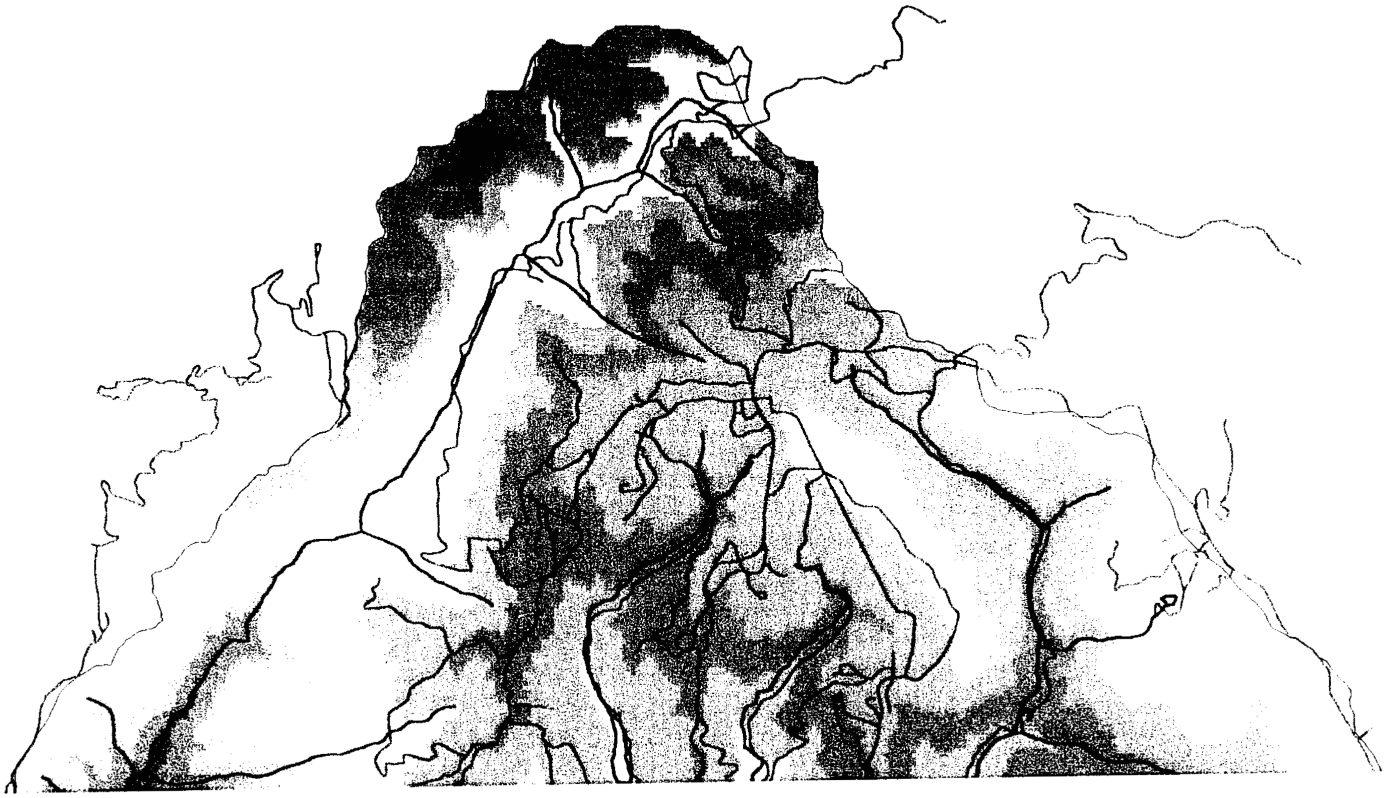


FIG. 1.

Relief Map
Scotts Creek



ROAD INVENTORY

The purposes of the road inventory were to: 1) identify historic and recent sources of erosion and sedimentation related to roads, 2) determine sites related to roads which have the potential to deliver sediment to streams in the future, and 3) identify remedial treatments which could be employed to reduce future sediment production from roads and reduce sediment delivery to streams in the watershed.

The inventory and analysis of field findings describe the impacts of roads in the areas of the watershed included in the survey. Aerial photographs from 1928 through 1998 were utilized in the road inventory to assist in determining the approximate time of construction of the various roads, since this impacts the standards to which the roads were constructed. Due to an extensive logging history and construction of a widespread system of fire trails built around 1948, the watershed has an intricate network of roads in all manner of conditions. *Figure 3* shows the road system in the watershed and the year in which the road segments were observed on the aerial photographs. Table 1 summarizes the length of road constructed in each of the time periods reflected on the photograph sets.

Table One. Road Construction History in Scotts Creek Watershed.

Date of Photo Set	Miles of New Road
1928	27.12
1956	90.48
1974	19.93
1994	3.6
Total	141.13

Field inventories were conducted to determine past sediment production and yield from the road network (including both landslide and fluvial erosion). Included in the survey work was the location and volume of future preventable road-related sediment sources if storm proofing of roads was undertaken. A database of inventoried sites contains information on past and future erosion and recommended remediation treatments to reduce potential sediment delivery to creeks.

MAP- Road Construction History Scotts Creek

Map too large for scanner

LANDSLIDES

The landslide identification and investigation of the Scotts Creek watershed has consisted of several phases. The investigation started with review of time series of aerial photographs by one of the slide team's geologists, Roberta Smith. The SCWC had a color set of aerial photographs flown after the El Nino winter 1997-1998 triggered numerous landslides in the watershed. These photographs added to the earlier coverage which was available. Older photographs used were flown by Big Creek Lumber Company. Many landslides are recognizable on aerial photographs. This includes large old landslides and some smaller more recent landslides.

Relevant geologic maps (Clark, 1981; 1984; Brabb, 1986; 1989; 1997) and soil maps (Bowman and Estrada, 1981) were also reviewed. Smith, who had done earlier work on 1982 landslides in the watershed, and had studied landslides and other aspects of the geology in the area over the past 20 years, (see e.g., Smith and Schipper, 1999) was able to identify important sites of study.

Land forms suggestive of landslides can be recognized in topography thus often such maps are examined for evidence of landsliding. Landslide maps are also placed on a topgographic base. The existing landslide maps, on topographic bases, of Santa Cruz County (Cooper-Clark and Associates, 1974, Preliminary Map of Landslide Deposits, for the County of Santa Cruz Seismic Safety Element of the General Plan, 1975, scale 1 inch = 1 mile) and their background 71/2 minute quadrangle maps, (scale 1 inch = 2000 feet) were examined closely. So was a more local and detailed map prepared by Weber, Nolan, and Zinn (19--; scale 1 inch = 1000 feet) which shows faults and landslides in a coastal area including the lower Scotts Creek watershed (All the landslides on these maps were identified by the map markers from aerial photograph analysis, not field surveys.)
The next phase of investigation involved reconnaissance fieldwork in the watershed. The Big Creek drainage, downstream from just above the upper falls was examined, with spot checks at some locations above the upper falls. The Little Creek drainage was also examined downstream of the confluence of the north and south forks, viewing locations along the creek and upslope along roads. Smith also traversed the ridgelines separating the Big and Little Creek drainages and portions of the ridgelines between the Big and Mill Creek drainages and the Scotts and Waddel Creek drainages. Portions of the upper Scotts Creek and lower Mill Creek drainages and the entire stretch of Scotts Creek from the Northern Swanton Bridge crossing down to the estuary were investigated. Smaller subwatersheds (e.g., Archibald Creek, Winters Creek) were checked briefly as well. Using a Survey Inventory Form developed by the SCWC, the team was able to evaluate sites and their affect on the watershed. With this information, the slide survey team was able to suggest remediation where possible. Based on criteria such as accessibility, financial feasibility(based on perceived benefit versus perceived cost), fisheries benefit etc. several priority sites were chosen.

GEOLOGIC CONTROLS

Structure

The Scotts Creek watershed is part of the Ben Lomond Mountain structural block. Along the southwest (west-southwest to south-southwest) side of the Ben Lomond fault, the terrain has been uplifted and tilted southwesterly toward the ocean and the mainly offshore San Gregorio fault over at least the past 15 million years. During the latter part of that time, there has also been relative uplift of the land above sea level along the front of the block (as elsewhere along the Santa Cruz – San Mateo coast). Even with the uplift, the block tilts oceanward. At the same time, land above sea level has been subject to geologically rapid erosion, mass wasting (=landsliding), and downcutting by streams. This has produced a terrain whose ridge lines mainly descend gently to moderately oceanward, roughly southwesterly (representing the tilted block). Between the ridgelines are the steep canyons cut by stream erosion and mass wasting; they essentially parallel the ridgelines. Side drainages form a very roughly dendritic pattern joining the main drainages.

Stratigraphy and Its Relationship to Structure

The oldest rocks of the Ben Lomond Mountain block are the metasedimentary schist and crystalline limestone which were widely intruded in Mesozoic time (70+ million years ago) by granitic magmas; now the granitic rocks are much more widespread than the metasedimentary rocks. These older "basement" rocks form the geologic bedrock (underlying soil and surficial deposits from landslides and other sources) found on the lower slopes and inland portions of the Scotts Creek watershed. Erosion and landsliding have removed the younger overlying sedimentary rocks at these locations.

During the past 65 million years, sediments were deposited over the granitic and metamorphic rocks. These sediments subsequently sequentially lithified by the weight and temperature induced by the younger overlying series of sediment. However, because of the ongoing tectonic activity of the area, the sequence of sediments/sedimentary rocks is nowhere complete and now includes only rocks of particular ages in particular subareas. Thus, the older sedimentary rocks are only found in the upland interior portions of the watershed, where they are locally exposed at ground surface and locally overlain by the younger sedimentary rocks. Then, moving southwesterly oceanward, it can be seen that the younger sedimentary rocks were directly deposited upon the granitic rocks. The older sedimentary rocks "pinch out." This can be seen along ridgelines and on canyon slopes where the bedrock is exposed. Locally, this leaves a thinning wedge of somewhat older sandstone and mainly the overlying/younger mudstone resting on the granitic rock. Again, the older "deeper" rocks of the area have been exposed by erosion and mass wasting largely as stream cut canyons have cut down through the terrain.

The contact between the sedimentary rocks and underlying older granitic and metamorphic rocks on which the sedimentary rocks were deposited inclines oceanward as do the beds of the overlying sedimentary rocks. This all reflects the continuing tectonic uplift of the general area southwest of the San Andreas fault and of the Ben Lomond fault in particular. Again, this uplift has tilted the Ben Lomond Mountain block southwesterly oceanward – toward the now largely offshore San Gregorio fault. The result is that in the oceanward and lower frontal elevation portion of the watershed, only the youngest sedimentary rocks, of the Santa Cruz mudstone, are found. This is true both on the ridgelines and on canyon side slopes. The granitic rocks would be found by drilling to some depths but are no longer exposed at the surface. Again, this is because the whole Ben Lomond Mountain block tilts southwesterly oceanward.

A feature of most fine-grained sedimentary rocks, such as the Santa Cruz mudstone, is that they are deposited in recognizable layers or beds. The beds of the Santa Cruz mudstone, having been deposited as beds offshore in relatively deep marine waters, would originally have been horizontal. With the later uplift and oceanward tilt of the Ben Lomond Mountain tectonic block, the beds too were tilted. The mudstone beds now mainly tilt or "dip" gently to moderately oceanward southwesterly. This can be clearly seen where the rock is exposed.

Besides being bedded, the mudstone is highly fractured (as is the granitic rock and most rocks in the general area). This is consistent with an area history of ongoing fault-related tectonic movement. The prevailing fracture orientations are steep, or fracture planes dip steeply. They intersect bedding planes at sharp angles. (Thus, as the rock weathers, angular rock fragments are produced readily.) Any persistent planar feature (bedding or fracture planes) in rock can relate closely with landsliding in that rock. This is discussed below.

Geologic structure does not appear to play a controlling role in landsliding on the side slopes in the Scotts Creek watershed. As it often is significant, this is an important finding. As noted, bedding planes in the Santa Cruz mudstone bedrock mainly dip (=incline) fairly gently oceanward, parallel with the tilt of the Ben Lomond Mountain structural block. This inclination is at approximately 90 degrees to the main canyon side slopes, versus parallel or subparallel. This means that the bedding planes do not act as slip or slide planes on the main canyon side slopes. Yet, bedding dips may be "adverse" to the stability of the ridge line front slopes which descend into Swanton Valley – because they parallel those front slopes. Evidence of numerous large-scale landslides can be seen along these slopes.

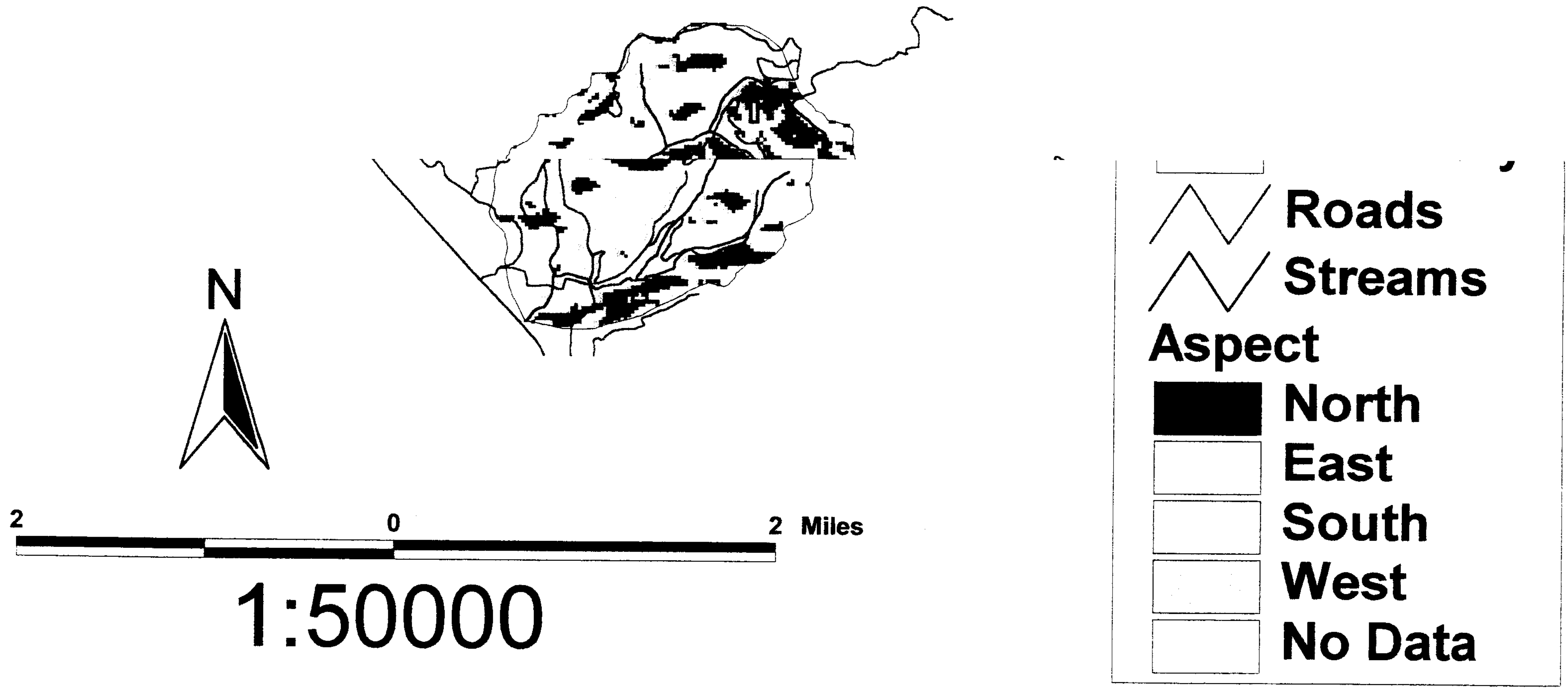
Prevailing and pervasive fracture patterns appear to be steep and not to parallel the side slopes. It may be, however, that some of these fracture directions do subparallel side slopes enough that the fractures become "adverse" or adversely inclining planar features which can act as slip or slide planes. This would have to be investigated further, but no compelling relation was seen to exist.

CONTROLS ON LANDSLIDING

Slope Aspect

Together with the overall descent oceanward of the terrain, the canyons of the watershed drain south-southwesterly to west southwesterly. Thus, side slopes predominantly face (=aspect) roughly easterly to southerly and westerly to northerly (*Figure 4*). Slope aspect appears to play or to have played a significant role in massive (=large-scale) landsliding in the watershed. The roughly west-facing slopes tend to feature large (older) rotational slumps of bedrock, with one to a descending series of "unit surfaces" (bench-like tops of descended blocks or masses). This is typical of rotational slumps. Translational slides and flows also are represented on west-facing slopes, but aerial

Aspect
Scotts Creek



photographs and distance views show dramatic (old) rotational slump development on west-facing slopes.

The steep roughly east-facing slopes, on the other hand, tend to feature long shallower translational slides and flows. Evacuation scars of such slides can be recognized on aerial photographs and by arcuate slope shapes seen along ridgelines and below.

Slope aspect relates closely to available sunshine, daily (including time of day) and over time. Thus, insolation and resultant ground saturation patterns probably control or play the triggering role in these two patterns of large-scale landsliding. That is, the roughly west-facing slopes retain rainfall-induced ground saturation longer and the ground water is therefore allowed to penetrate more deeply. Yet, the smaller-scale landsliding which is more common (especially in a time frame of concern) mainly takes place relatively low on canyon slopes and does not correlate as well with slope aspect. In part, this may be due to the fact that canyons are narrow and lower slopes of whatever aspect are sheltered from sunshine.

These lower-slope landslides in the upper valley of Scotts Creek (above Swanton Road) and the other similar canyons of the Scotts Creek drainage/watershed may occur about as commonly on both sides of these steep SSW- to WSW-trending canyons. Some differences in landslide style and abundance may result overall from slope-aspect-induced differences in slope shape and (larger-scale) landslide types. Recall that NW-facing slopes tend to feature large old slump blocks with "stair step" topography. SE-facing slopes tend to be long, steep, and straight (note, these are tendencies and certainly do not hold true in all cases). Yet, both larger-scale processes, in combination with geologically rapid uplift and concomitant creek downcutting, tend to produce extensive "inner gorges" with steep slopes on both sides.

It is in this setting that many to most of the landslides that can deliver sedimentary debris to the creeks take place. Probably most such slides begin with (very) small rotational slumps at their tops – where soil and some underlying weathered bedrock (or older landslide deposits) give way – usually because of ground saturation. These slumps may continue downslope as slipping, sliding, translational movements of surficial materials that have lost strength to the point that they fail under saturated conditions. Often the movement rapidly becomes by flowage because of the saturation of the materials, hence debris flows. This process can occur on straight slopes but is more common in draws, where soil and weathered surface materials are thicker and channels are already present. In some cases, the thickness of weathered materials, colluvial soil, or colluvium, or debris flow deposits, may not be appreciated when observing the surface of the slope: swales may be visible but may appear relatively shallow, while they contain greater thicknesses of such potentially relatively unstable materials than the seeming shallowness would suggest. Also colluvial soil and landslide-derived colluvium have already begun a downslope movement process.

Slope Length and Slope Steepness in the Upper Watershed

Slope length does not appear to correlate strongly with landsliding, though, obviously, the longer a slope, the longer a landslide on that slope could be. Slope steepness would appear to play the role that the steeper the slope, the more pronounced the gravitational force to induce slope failure (*Figure 5*). As noted, the roughly east-facing slopes may

Map: Slope Scotts Creek

Map too large to scan

overall be steeper, relating to the presence of "stair-stepped" rotational slumps on west-facing slopes. Yet, the west-facing slope segments between "benches" are also steep. Overall, the slopes in the watershed tend to be steep to very steep. There may be a trend to steeper slopes lower on canyon sides. This is pronounced for "inner gorges" just above streams. This certainly contributes to landsliding on these lower slopes.

Overall, the steeper slopes near and in the canyon bottoms are the most subject to current landsliding. This is because of slope steepness, thickness of unstable materials, and ground saturation – which is greater on these lower slopes (regardless of slope aspect). It is often difficult to know if a landslide began at creek level and migrated upslope or began above and slid down to the creek. Creek cutting at toes of slopes plays a significant role by triggering bank failures. Creek downcutting has created the steep "inner gorge" slopes, so is somewhat indirectly also responsible for instability in many cases.

Swanton Valley

The situation in Swanton Valley differs from that in the upper watershed (discussed above). Landslide distribution differs from one side of the SSE-trending valley to the other, for geological reasons. The orientation of Swanton Valley is something of a geological enigma, though it may relate to the San Gregorio fault. The valley crosses the main SW-tilting/descending structure of the Ben Lomond Mountain structural block's drainage. Thus, the moderate but dissected "front slopes" on the east side of Swanton Valley represent the more-common SW ends of the ridges of the Ben Lomond Mountain block. The slope on the west side of Swanton Valley is lower but straighter and steeper and of a different origin. This results in a somewhat different landslide pattern.

Very shallow soil slips are more common on the west side; these occur at varying elevations on the straight very steep slope segments underlain directly by bedrock. Relatively small debris flows occur as commonly on both sides of the valley, but tend to differ in origin. Those on the east side are more likely to arise in small slumps at or near the heads of the indented small side canyons. Those on the west side, though some descend slope indentations/draws similarly, tend to arise in failures at or above the sharp slope breaks to marine terrace tops, located at the top west side of the valley.

Some of the west-side debris flows and soil slips may reach Scotts Creek. Some, however, barely reach the valley floor. Their runout areas on gentle valley side slopes (in the relatively wide valley) frequently form alluvial and colluvial deposits along the valley side. It appears that debris flows from the east side of the valley more frequently reach the creek as well as forming deposits in the lower portions of their side valleys. This may result from a greater source area, thus larger volumes.

Weathering

Weathering is a process that degrades all rocks at and near the land's surface. Chemical weathering is effected by water, weak acids, and air, and includes complex chemical reactions with plant roots. At the same time, water and gravity add mechanical weathering. In combination with and influenced by some other factors, weathering turns the surface portion of rock to soil over time. Weathered rock and soil are much weaker than unweathered bedrock from a slope stability/landsliding perspective.

The granitic rock in the area tends to be deeply weathered. As time passes, weathering penetrates deeper and deeper into the rock – until the weathered rock (and overlying soil) is removed by erosion or landsliding. The abundant fractures in the rock assist weathering solutions to penetrate the rock. The darker colored, more iron-rich mineral grains in the rock weather most rapidly, together with the more abundant feldspar grains. These minerals change chemically to others and begin to dissolve or wash away. This leaves the resistant and abundant quartz grains intact as sand, though the rock itself is breaking down. The weathered zone in the granitic rocks may be variably many feet thick in this area. This material becomes subject to erosion and landsliding.

Unweathered mudstone is not nearly as dense, heavy, or hard as unweathered granitic rock. If the mudstone is removed (as by landsliding) from its place, it breaks down much more readily during transport than does the granitic rock. This can clearly be seen in the resistance and relative abundance of granitic cobbles and boulders in streams in this area compared to mudstone cobbles and boulders. Yet, the local mudstone tends not to weather nearly so deeply in place as does the granitic rock. The actual minerals forming the mudstone may well be more resistant to chemical weathering as it is highly siliceous. Another related and relevant difference is that the contact between the surface soil and underlying granitic parent material is gradational, whereas it is sharper between the soil and mudstone parent material.

The differences in weathering of these two predominant rock types may predispose them to some differences in landslide susceptibility and style. The less abundant sandstones and schists may weather more like the granite. Landslide masses and blocks which have already moved have had their strengths reduced and become more porous and permeable than they were when they were bedrock in place, no matter the rock type. There are many landslide blocks and masses composed of mudstone and mudstone rubble on slopes in the watershed. There also are some granitic landslide masses.

Relation of Geologic Materials to Landsliding

Landslides are seen commonly in both the two abundant rock types in the watershed, quartz diorite granitic and siliceous mudstone rocks, though there may be some differences in landslide types. (Landslides are also seen in the less common rock types.) Such differences do not, however, appear to override the slope aspect relative abundance patterns of rotational slumps (west or northwest slopes) and long translational slides (east or southeast slopes). Geologic structure, which may act as slide planes, is seen on ridge line front slopes along the east side of Swanton Valley, but not on the main canyon side slopes. Weathering of geologic materials (bedrock and even of preexisting transported deposits perched on slopes) and resultant soil formation produces weakened near-surface materials. This plays a very significant role in landsliding, particularly in the relatively shallow slides that are of the most concern in the present context – as these relatively shallow slides are the most likely to occur and to deposit sediment into the creeks in a given time frame of concern. Landsliding within transported masses or blocks most likely is (much) more common than in undisturbed bedrock in place. Yet, as weathering progresses in bedrock, it is subject to landsliding. The thick weathered zones (of whatever source material) become particularly unstable at their steep slopes, especially in the lower portions of the canyons, and are prone to failure when triggered by heavy ground-saturating rainfall and earthquakes.

Slide Types

Many slides fall into an "in-between" category between rotational slumps and translations. A complete range exists between "pure" rotational slumps and translational slides which have moved or "translated" more-or-less straight down the slopes in planar fashion. Debris flows may also accompany either slumps or, more often, translations, or may constitute much to all of an event.

<u>Rotational slumps</u> are landslides wherein a block or mass of rock (and/or any other geological material, e.g., a deposit or soil) begins to detach from its position on the slope and rotates backward or back-tilts as it does so. The slide or slip plane develops a bowl or arcuate shape in this area as the mass moves; this is the "listric" portion of the slide plane. All of the slide material may evacuate this area and move on down the slope or, commonly, a portion of the slide mass remains resting on the more gently inclining part of the slide plane. This process of breakup of the slide can result in the slide including up to several scarps downslope of the head scarp, scarps from which material moved away and may have (temporarily) formed slide deposits. The overall appearance of such a slide may be of a series of "stair steps" of scarps and downslid blocks and/or masses. (The gentle intermediate slopes of such large landslide features have often been chosen as building sites in developed areas of the Santa Cruz Mountains.) The lowermost "toe" areas of both rotational and translational slides are often tumbled, jumbled masses of material, which may have moved by sliding or flowing. These are susceptible to movement by flowage and may even turn upon reaching valley bottoms and flow on down valleys. Yet, especially if a slide has reached valley bottom and buttressed against the slope on the opposite side of the valley before a breakup into such a toe area has taken place, the slide mass may be relatively undisturbed. In the Scotts Creek watershed, some such buttressed toe areas may be seen to have been exposed later by creek erosion and downcutting.

<u>Translational slides</u> differ from rotational slumps largely in the relatively smaller size or extent of the rotational or listric head area of the slide, often producing a less deep or thick slide. In addition, the movement of the slide material tends to involve more breakup and internal movement within the mass, producing a more jumbled-appearing landslide deposit. The type of movement may also frequently grade into, or include, flowage, as much of the mass may be charged with water. As noted, however, gradation among landslide types is common.

<u>Speeds</u> of landslides and debris flows may vary greatly as well. Rates as slow as very occasional reactivation (e.g., by ground saturation or earthquake) with a few inches or feet of movement may be taking place. Slow continuous though usually episodic movement may also occur, especially with near-surface slides. Rates of landslide events may be a few feet per hour or a few feet per second. Some debris flows travel at avalanche speeds.

<u>Sizes</u> of landslides also vary greatly. They can range from a few inches or feet in surficial dimension to a mile or more in width and at least several hundred feet in length. In depth, slides also vary, usually with their width and length dimensions, but with some types tending to be deeper-seated than others. Some slides may be very surficial and involve only near-surface soil materials. Others have a greater depth component. The

type of material which fails and the mechanism of failure plays a large role in the relative depth. Overall, rotational slumps of bedrock tend to be the deepest-seated slides, at least in this area. The slides of greatest concern and relevance in the present context of current sediment delivery to streams tend to be the relatively smaller-scale landslides of surface and near-surface materials. These are the slides most likely to occur within a time frame of concern. It is true, however, that the larger of these "smaller-scale" landslides are and will be those which deliver the most sediment to the streams, if their toes or runouts reach the streams.

Landslide Reactivation Potential

Reactivation of the larger older landslides is very unlikely in a time frame of concern. This is especially true if the consideration is delivery of sediment to creeks, with one exception involving basal, i.e., toe portions of slide masses which were greatly disturbed during their original movements (see below). The larger older rotational slumps of bedrock are particularly unlikely to produce sediment. This is because although the rock shatters some during the downslope movement, it does not break up completely and the resultant landslide deposit is more a block than a comminuted jumbled mass. Some larger landslides do break up and involve separate incoherent movement of fine to very coarse-grained (cobble- to boulder-sized) fragments within the landslide mass. There is a range or continuum between (1) large slides in which the bedrock in the landslide deposit appears hardly disturbed though it may have moved some distance and (2) slides in which the bedrock and surface materials which moved have been so broken up and subject to movements internal to the mass as to lose most cohesion and end up as a more-or-less fine-grained ground mass containing angular fragments (pebbles, cobbles, boulders) oriented in all directions.

In the first case, the fact that a landslide has taken place may be revealed mainly by the shape of the landslide deposited (a back-tilted subarcuate block with a relatively gently sloping top or "unit surface") and (2) where the landslide deposit is exposed, as in a stream bank or road cut, a somewhat differing orientation of the beds (if the rock is bedded) than would be expected if the rock were in-place, i.e., undisturbed/not slid.

In the second case, that of the broken-up landslide debris deposit/mass, there may also be a relatively gently sloping top or unit surface to the landslide mass (though often not as extensive as with a more characteristic rotational slump of bedrock) – but the more broken-up the block or mass and therefore more porous and permeable it is, the more likely the landslide plane will become saturated and thus induce remobilization of the landslide mass. Further, because of saturation of the mass, the more likely portions of it are to remobilize as slides (smaller than the original) forming a new slide plane within the older slide mass.

Some slides or the toes of some slides have descended to the base of the slopes/valley or canyon bottom. Then the toes of the slides can be exposed by creek downcutting through the basal slide mass. This exposes relatively unstable material (the slide mass) on the steep creek cut bank or slope. The process of creek downcutting (or other activity, such as road cutting) which achieved such a steep bank or slope may also have "oversteepened" it; i.e., made the slope or bank steeper than it can remain stable. Then, reactivation of sliding in the toe area of the landslide deposit may take place. (Again, the more broken-up the landslide mass, the more likely there will be such partial slide reactivation.) This, then also may result in progressive headward (=upslope) migration of the "new" slide and thus reactivation of more of the older slide.

As the Santa Cruz Mountains continue to uplift tectonically and, concomitantly, creeks continue to cut down, the canyons remain steep, especially in their lower portions or "inner gorges." This works to increase the potential for reactivation or activation of landsliding of marginally stable materials. Such materials would include porous and permeable older landslide deposits and also thickening and developing surficial soil (usually itself colluvial, i.e., moving downslope by creep as it forms) and underlying deposits and/or weathering bedrock (in place) parent material to the soil.

This then brings us to the point of considering the smaller-scale relatively shallow landslides which are most likely to occur, and to deliver sediments to creeks in a time frame of concern. In the Scotts Creek watershed and similar environments, most of these landslides have/do/will occur(ed) on the steeper slopes. Many of the steeper slopes are low in the canyons – very steep "inner gorges" and steep to moderately steep slopes adjacent above them. Put another way, inner gorges feature very steep slopes; steep slopes also can be found higher on canyon sides for various geological reasons, including past landsliding.

Slope aspect also plays a role, as described above. However, inner gorges, of whatever aspects, are sheltered from sunshine and receive much percolating groundwater as well as surface rainwater and flow. This keeps these slopes nearer saturation more of the time than are slopes higher on canyon sides. The saturation itself may lead to slope failure, plus it causes geologic materials to weather more rapidly and to greater depths than is the case higher on canyon or valley sides. These weathered materials are less stable and more prone to landsliding than are less-weathered rocks and even older landslide deposits.

With and without previous landsliding and various forms of its reactivation, landsliding will continue to occur in this watershed in various physiographic and geologic settings and by several mechanisms.

STORM HISTORY

No records of early flood events were found in association with these surveys. More recent flood information comes from long-time residents of the Swanton area and their personal recognition of past flood events. Most flood events seem to occur during periods of intense rainfall following earlier rains which have saturated the soils. Santa Cruz County is known to have some of the highest rainfall intensities along the central coast (*Figure 6*).

Major flooding events have occurred in 1940, 1955, 1982, and 1998. Prior to 1998 the floods of 1955 were considered by most to have been the most damaging. Some lives were lost in the 1955 flooding. The 1998 floods exceeded the levels recorded in 1955, although there are no official stage records from either of these floods. There was a USGS gauging station in operation for a period of time on Scotts Creek; however, all major flood events were missed by this operation. The gauging station was abandoned by the USGS and was reinstrumented in 1997 by Cal Poly State University. The level control dam required for successful gauging was damaged beyond repair by the February

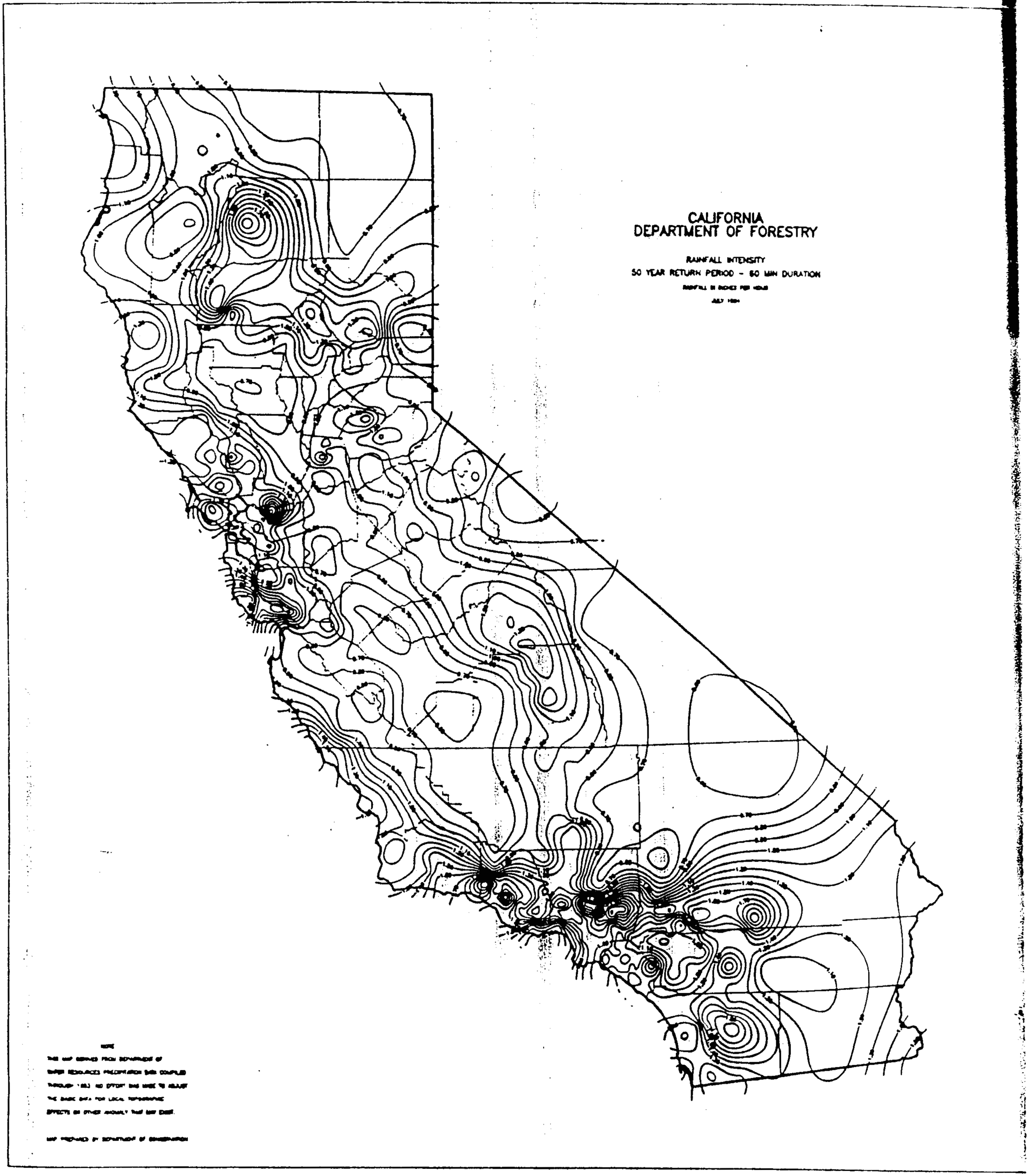

CALIFORNIA
DEPARTMENT OF FORESTRY
RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 60 MIN DURATION

FIG 6

1998 storms, so no data are currently being collected. However, the stage recording equipment is currently in place.

All the major storm and flood events have resulted in dramatic changes in riparian vegetation. The age of the alders along the streams in the watershed dates back to these specific flood events. Most of the mature alders date from the 1955 flood event, when major scouring of the stream courses took place due to high flows and large amounts of woody debris. The impact of this is readily apparent in Little Creek on the 1956 set of aerial photographs. The channel from the site of a large landslide down to the confluence with Scotts Creek shows extensive scouring. Similar flushes of alder reproduction have occurred from the 1982 and 1998 floods. Many of the 1982 alder crop were lost during the flood on 1998.

Limited precipitation records occur for the Scotts Creek Watershed. Barbara and Lud McCrary, long time residents of the Swanton area, have been maintaining precipitation records since 1955, and the five top two-month rainfall totals for the time they have been maintaining records are listed in Table 3.

Table 3. Rainfall Records for Top Five Two Heaviest Months by Year

YEAR	MONTH	MONTHLY PPT	YEAR TOT
1998	JAN	17.05	71.45
	FEB	21.75	
1955	DEC	23.83	39.00
	JAN	8.12	
1983	FEB	11.14	59.25
	MAR	15.99	
1969	JAN	12.75	43.80
	FEB	14.30	
1993	JAN	11.95	44.43
	FEB	13.30	

WATERSHED LANDUSE HISTORY RELATIVE TO EROSION AND LANDSLIDING

Introduction

Relationships between human activity, erosion and landsliding in the watershed can be divided by types of human activity: logging; residential use; other silvicultural activities; agriculture involving tilling the soil; animal activity and feral pig rooting and wallowing; livestock grazing; water diversions; roads and trails.

To some extent, these land uses have taken place in the watershed since European-Americans have dwelled there. Fires related to human activities may predate these activities as they were set by native Americans. Fires have occurred since as well. They would occur naturally also, though likely not as frequently.

Logging

Logging in the Scotts Creek Watershed began in the late 1800s with the earliest known logging occurring on Big Creek in the 1890s. Another area on Mill Creek was logged around 1906. This early logging was limited since there were no railroads in the area at the time. Much of the early skidding of logs was done by oxen. Some of the early logging operations were producing split wood products on site. Lumber was milled locally at a saw mill on Mill Creek. The mill site is currently part of the residential area occupied by the Ben Wilson family. Many of these areas were logged for a long period of time as markets and loggers changed the concept of what had value.

The next logging was on a much larger scale following the 1906 earthquake in San Francisco. The San Vincente Lumber Company constructed a railroad up Little Creek and over into the upper reaches of Big Creek and into Deadman's Gulch starting in 1907. These logging operations continued until around 1920, and the rails were pulled for salvage in 1921. The San Vincente logging spur connected to the Ocean Shore Railroad near the confluence of Little Creek and Scotts Creek. The Ocean Shore Railroad terminated in the meadow area between Little Creek and Big Creek. The logging in this operation was clear cutting with steam donkeys used for cable yarding. The yarding was generally done straight up and down the slopes to the railroad grade. The railroad grade constructed up Little Creek is still used for access today and was used as a haul road for logs in more recent sales. Railroad ties are still evident in some sections of the roadbed. Some of the stream crossings on this road remain from the railroad days and consist of earthen fill and some type of Humboldt crossing. Hand stacked rock walls are present on some of these fills. Some sections of the old railroad grade are abandoned for vehicular use but are currently used by hikers and equestrians.

The next large scale round of logging in Scotts Creek took place starting in the late 1940s and continued to move around to various locations in Scotts Creek, Little Creek, Mill Creek, Winter Creek, Archibald Creek and Queseria Creek until the 1960s. This logging was largely tractor skidding with extensive skid road construction, but there was little permanent road construction. Many of the roads constructed during this phase have been abandoned and do not have stream crossings in place. In some cases the class three and four drainages were utilized as skid trails during the summer when there was no water flow. Depending on the stochastic events during this time, this practice may have led to sedimentation in the watershed. Since these roads have been abandoned and the creeks have generally healed these sites there is no evidence of the effects of this practice. They currently seem to be having little impact on the watershed. Exceptions to this are the roads to residential access. Some used to access residents and ranches were constructed originally as truck or tractor roads and converted to permanent year round use as residences were constructed in the watershed.

Current logging activity has been centered in the upper Scotts, Little and Archibald Creek drainages. Permanent seasonal roads are in place in these drainages, some of which originated from the early railroad logging. Other roads were constructed in the 1980s during logging in the second-growth forests that resulted from the railroad logging and clear cutting. These harvests all utilized selective cutting. During these harvests in 1980, 1988 and 1989 and 1993 and 1994, steep ground was generally cable yarded using the standing skyline method and less steep ground was tractor yarded.

The early logging which concluded in the early 1920s resulted in harvesting of approximately 30 percent of the Scotts Creek Watershed. During the logging from the 1940s into the 1960s an additional 9 percent was logged. The total logging prior to the enactment of the Forest Practices Act in 1974 was 39 percent. The logging that has taken place since that time has resulted in the harvest of 17 percent. Much of the area logged since 1970 was logged prior to the end of the early logging in the 1920s, so the total area logged is 39 percent. Table 1 presents the logging history for the watershed and *Figure 7* shows the harvest areas in the watershed.

Table Two: Logging History of the Scotts Creek Watershed

YEAR OF HARVEST	METHOD OF HARVEST	WATERSHED	ACRES HARVESTED	PERCENT OF WATERSHED
1890	CLEARCUT	BIG CREEK	795	4.206
1890 - 1915	SELECTION	BOYER CREEK	1,298	2.856
1890 - 1940	SELECTION	BIG CREEK	1,006	5.321
1898	SELECTION	MILL CREEK	210	1.109
1906	CLEARCUT	MILL CREEK	316	1.67
1906	CLEARCUT	MILL CREEK	541	2.863
1910 - 1920	CLEARCUT	LITTLE CREEK	1,845	9.758
1915	SELECTION	SCOTTS CREEK	414	2.19
1946	SELECTION	SCOTTS CREEK	163	.862
1946	SELECTION	MILL CREEK	37	.196
1950 - 1965	SELECTION	SCOTTS CREEK	16	.085
1955	SELECTION	SCOTTS CREEK	248	1.312
1955	SELECTION	SCOTTS CREEK	242	1.28
1955	SELECTION	SCOTTS CREEK	246	1.301
1955	SELECTION	SCOTTS CREEK	23	.122
1960	SELECTION	SCOTTS CREEK	754	3.99
1955	SELECTION	SCOTTS CREEK	237	1.253
1956	SELECTION	MILL CREEK	218	1.153
1960 - 1999	SELECTION	BIG CREEK	2,338	12.368
1989	SELECTION	LITTLE	343	1.81
1994	SELECTION	LITTLE	533	2.82
TOTALS			8,609	41..27

The totals do not include data from 1989 or 1994, since these areas had been harvested in the harvest that ended in the 1920's.

Early logging practices, with clear cutting in the watershed, led to landsliding immediately thereafter. This would have been surficial landsliding of the types of concern for sediment delivery into the creeks. There is no written history of such landsliding but photographs show bare slopes and railroad lines and roads. The affects of logging may have been similar to those of fires. Yet, within a relatively few years the slopes were revegetated and reforested naturally (as also with fires). This would have greatly limited opportunities for landsliding. As current logging is under the direction of Registered Professional Foresters and under the current legal requirements for this area, no recent landslides have occurred in relation to logging practices.

MAP: Logging History Scotts Creek
Map too large to scan

There are people who speculate that the early clear-cut logging produced conditions which are still today causing landsliding in the Santa Cruz Mountains. Little to no geologic evidence appears to support this belief except for the continued existence of some roads and landings. These often have been converted to other uses in developed areas (though mainly not in the Scotts Creek watershed).

Residential Use
Most buildings in the watershed have been constructed on natural flats and flood plains. The few buildings on heavily graded sites feature cuts at their upslope sides and fills at their downslope sides. Log landings can also be constructed in this manner but again, level areas for log landings are typically used in the watershed. Heavy grading can produce both unstable cuts and fills. Cuts may be oversteepened. Fills may need to be keyed in, to be compacted better, and to have water drained off in a non-saturating, nonerosive manner. One log landing was seen to have experienced fill failure, which slid and flowed downslope. No other evidence of cut and fill problems associated with residential use were found in this study and these issues are dealt with in the State's Timber Harvest Rules and Regulations and by County Ordinances and enforcement. Management of surface runoff from houses can also alter the watershed system. It is important not to channel drainage such that landslides are triggered downslope. One landslide in winter 1997-98 appears to have originated as concentrated drainage from around a house on a ridge, then flowed down to a road and creek in the canyon bottom below. In another instance, a house's roof runoff created a new class 3 drainage.

Other Silvicultural Activities
Such activities include road and landing maintenance, removal of some temporary "structures" (e.g., stream crossings), tree planting, and designing and marking for subsequent timber harvests. The maintenance and removal work will lessen the potential for landsliding or soil loss. The other activities should have no affect on erosion or landsliding.

Crop Agriculture
Agriculture involving tilling of the ground was historically much more extensive in the Scotts Creek Watershed than is currently the practice. Agriculture probably started on a limited scale in the mid 1800s when much of the watershed, especially the lower portions of Scotts Creek and its tributaries were included in a Mexican Land Grant "Rancho Agua Puerca Y Las Trancas", which consisted of approximately 4800 acres. This originally was largely a cattle ranching operation with limited dairy activities. The next push for agriculture came with the homesteading of lands inland, adjacent to the Mexican Land Grant. This activity continued until in the 1880s and most of the acreage tilled was relatively small and most was in upland areas on some of the old marine terraces and other gentle slopes. Dairying was increasing at this time and there were several active small dairies, with the largest located along Queseria Creek in the lower portion of Scotts Creek. The old cheese house built in 1867 and the dairy barn built in the 1880s are still present and are used for agricultural operations on the Swanton Pacific Ranch.

During the early 1900s and extending to the late 1930s the crop agriculture in the Scotts Creek Watershed peaked. During this time there were extensive cropping operations between Scotts Creek and the Pacific Ocean with runoff draining oceanward. These operations were irrigated with water pumped from Scotts Creek to reservoirs on the ocean side of the creek. The pumping operation was located just below the confluence of Mill Creek and Scotts Creek. Remnants of the old dam and the cement tanks are still present along Scotts Creek. The old tanks and reservoir system for irrigation still exist on the ocean side of Scotts Creek; however, they have been abandoned for many years. Heavy cropping of the bottomlands along lower Scotts Creek extended into the 1990s.

Current crop agriculture is limited to operations on Swanton Pacific Ranch and home gardens of many of the resident. The Swanton Pacific Ranch tilled ground consists of approximately 115 acres with all but about 20 of that irrigated from two agricultural wells located in the lower watershed below the confluence of Winter and Scotts Creek. A diversion is also utilized during periods when creek flows permit. All cropping activities are certified organic, so pesticide use in the watershed by agriculture is very limited. Due to the nature of organic agriculture, nearly all of the ground is in cover crop during the winter rainy season. This helps reduce sediment production from the tilled ground.

The agriculture fields in the lower watershed flood on a regular basis during the winter months. Scotts Creek was levied in conjunction with the construction of the bridge over Scotts Creek when Highway 1 was built to bypass the Swanton Valley portion of the old Coastal Highway. These levees and the stream channel were maintained by the Army Corps of Engineers through 1982; however, since that time no channel dredging nor levee repair has taken place. As a result there is considerable aggradation in the channel in lower Scotts Creek, thus reducing channel capacity. The levees are breached in several places along their extent and water regularly flows through the breaches and out onto the agricultural fields.

Animal Activity, Livestock and Feral Pigs

Over concentrations of livestock and feral pigs (over time) can lead to soil denudation, compaction, stream bank failures and other disturbances. Erosion and degradation of water quality can result. Livestock access to springs and creeks is limited and controlled in the watershed. However, it has been observed by several landowners and landmanagers that feral pigs have rooted in natural springs which lead into creeks. The resulting break-up of peat in these areas is a fine sediment that is then washed into the larger streams during the rainy season. In February 2000 this ultra fine silt passed through the filters at the Monterey Bay Salmon and Trout Project rearing facilities and proved its deadly effectiveness by killing 50% of the recently spawned steelhead eggs. It is noted by landmanagers that much of the erosion found in pasture, crop and timberlands stems from lack of maintenance and erosion control on access roads.

Water Diversion

No problem with this type of water management was identified in the watershed. No extensive diversion systems exist. There are a few farm/stock ponds. One functional dam (on Mill Creek) and another old dam (on Boyer Creek) exist. No significant relation with landsliding was expected.

Roads and Trails

Systems of roads and trails are numerous within the watershed. These roads and trails cross canyon slopes and ridge lines. Many of these are more-or-less permanent but may experience only limited use during rainy seasons. Roads and trails may first have been extended throughout the watershed with the early farming and ranching, logging, fire suppression and related activities. Some of these routes even likely followed native American trails, though a history of this is lacking. As noted, any of the logging access routes were long-ago abandoned and evidence of them has tended to disappear. (They do not appear to have become sources of ongoing landsliding). Some of the early routes have continued in use, to facilitate other activities. Others have been added. Most of these routes are maintained in preparation for winter rains. This probably limits roads as (potential) sources of landslides.

Not many of the landslides recognized on aerial photographs appear to have been caused by roads except for very small "pop outs" on road cut banks. Where roads and trails were observed to have contributed to landsliding (in the past two decades), three conditions were commonly involved: oversteepened cuts and fills (fills on the outsides of roads and at stream crossings) and channelized flows along road surfaces insufficiently interrupted by water bars or rolling dips – flows which then exited roads at outer bends. Failed road culverts or crossings were also involved in a few cases.

In the cases of failed culverts or crossings, often the actual slope failure events (=landslides) were debris flows which originated upslope, swept down draws and overwhelmed culverts (culverts are not sized for debris flows) as they crossed roads, then flowed on down the draws below the roads. In these cases, it is difficult to implicate roads as causative of the landslides.

With those landslides involving roads, a few delivered sediment to the creeks; these mostly were the debris flows just mentioned. In cases of cut slope failure and often of failure unrelated to roads but descending from above, the road beds acted as catchment for some of the landslide debris (there is a good example on Mill Creek). This prevented (some) sediment from entering the creeks. It was commonly seen with roads paralleling creeks along valley/canyon bottoms. Yet, it is true that roads along creeks in canyon bottoms in particular (versus crossings slopes higher up) may contribute to triggering landslides which may deliver sediment into the creeks because of the road's proximity to the creeks. The roads in the bottom lands along Big Creek, Mill Creek and Scotts Creek have no cut bank. Failures of sidecast fill on the outsides of roads were also seen, sometimes furthered by trees pulling out of the slope.

Roads survey identification of sediment sources

A total of 162 sites were identified on the roads survey. These sites were found at an average of 2.8 sites per mile along the 57.3 miles that were inventoried in the watershed. Inventory Sites were distributed among many subwatersheds in the Scotts Creek watershed. The distribution by subwatershed is displayed in Table 4.

Table 4. Inventory Sites by Subwatershed

SubWatershed	Number of Sites
Queseria	7
Archibald	9
Winter	4
Little	15

Big	1
Mill	56
Boyer	55
Scotts	15

These inventory sites represented a variety of problems that were identified. Since all stream crossings were required to be inventoried, they made up the largest percentage of the inventory sites at 106 out of 162 or 65.4%. Stream crossings were also most prevalent among the sites that were rated as high in treatment immediacy with 16 out of 27 sites or 59.3%. This indicates that stream crossings are an important source of sediment production and treatment of those sites is considered a high priority. In general, 100 percent of the sediment produced at a stream crossing is delivered into the streams. Table 5 shows the number of sites by immediacy of treatment rating and the past and future erosion volumes as well as excavation volumes in cubic yards.

Table 5. Inventory Sites Summarized by Treatment Immediacy

Treatment Immediacy	Number	Past Sediment	Future Sediment	Excavation
High	27	7252	15755	1282
Moderately-High	33	2811	3417	598
Moderate	22	643	209	840
Moderately-Low	24	3696	3208	1610
Low	56	281	565	8692
Totals	162	14683	23154	13022

LANDSLIDE INVENTORY

The Process

On the ground and from the aerial photographs, we counted and made estimates of the numbers of recent (roughly the past decade or two) landslides (including reactivation of previous landsliding) in the Watershed. A landslide type and size and distribution versus time relationship was developed. Correlations with large-rainfall-winter events were recognized. Relationships also were sought between landsliding (of various kinds) and human activity. In the end, we focused on current landsliding because this is the landsliding of concern to current processes of transportation and sedimentation in the creeks in the watershed vis-à-vis anadromous fish and other members of the biotic community. Of the recent landslides, we tried to determine which slides delivered or could have delivered sediment to the creeks. Debris flows, massive slides directly above/adjacent to creeks, and stream bank failures (by a landslide process) were identified as those slides which accounted for almost all of the sediment to creeks, though most landslides did not deliver sediment to the creeks.

In the past two years of the present study, as noted above, we have focused on landslides which could have contributed sediment to the creeks in the Scotts Creek Watershed. We have done this to fulfill the requirements of the Department of Fish and Game Grant, as we understood them. This was to identify landslides which did and could, in the future, deliver sediment to the creeks, especially as affects anadromous fish spawning habitat. In addition, we considered mitigation which could be performed (feasibly) which could lessen the amounts of sediment delivered or lessen its impacts. A list of priority projects was created based on whether sites were accessible with the necessary equipment, whether projects were financially feasible(cost versus benefit), whether projects would benefit the fishery, and supported by the landowner. In all cases the projects were chosen to prevent future sediments from entering the watershed.

Landslides are natural to and widespread in the watershed's steep terrain. There were a few cases of accelerated erosion and landsliding identified, but mainly the process was/is natural. We have examined both roads and landslides, independently and together, in the context of the present grant, but we also have identified stream bank erosion as a third regular source of sediment into the creeks. Stream bank erosion can relate to or grade into landsliding and be influenced by roads as well, but also can act and be viewed separately.

Findings

The Scotts Creek watershed is marked by landslides. Aerial photographs show evidence of abundant landslides, landslide deposits and landslide scars. These represent a long span of time. The large rotational slumps of bedrock probably originated as much as 10,000 – 20,000 years ago (dates of prehistoric slides are not known). Large translational slides which can still be recognized may represent nearly as extensive a time period (up to several thousand years). Evidence of debris flows tends to be transitory, though these events are common and of various sizes. If a debris flow runs out of water and changes to a slide and/or comes to a halt, a landslide deposit may form. Otherwise, the transported material moves down the streams, forming bed load or going on out to sea.

The occurrences of landslides are consistent with geologically rapid uplift of the land with concomitant mass wasting, downcutting and canyon and ridge line development under the influence of gravity aided by water (erosion and saturation). The watershed features mainly granitic "basement" rocks and much younger marine sedimentary rocks, predominantly mudstone.

Main canyonside slopes predominantly face roughly west to northwest and east to southeast; landsliding has been common on both slope aspects and also on lesser-developed slope aspects; landslide type differs some between the two main canyonside slope aspects. Geologic structure, however, appears to play only a minor role, except on "front slopes" on the east side of Swanton Valley where beds in the mudstone bedrock dip (=incline) parallel to the slope – and are thus "adverse" to slope stability.

Much of the larger-scale landsliding probably is relatively old (to several thousand years). Smaller-scale landsliding during the same time frame would also have taken place abundantly but evidence of it would have been obliterated over time. The likelihood of large-scale landsliding now, in current time, is relatively low. Smaller-scale landsliding can, however, be expected to continue to occur regularly, with high intensity rains, ground saturation and earthquakes. It is this relatively-small-scale landsliding which is of concern in the present context. Much of this landsliding would take place with or without human activities in the watershed, as those activities are currently practiced.

Between 125 and 150 relatively shallow and small landslides are estimated to have taken place in the El Nino winter of 1997-98. Earlier, in 1982, a similar number of landslides occurred in the watershed. Most 1992 and 1998 slides were, and can, in the future, be expected to be low on steep canyonside slopes and "inner gorges" of streams. (Over time, landsliding involving all elevations on slopes up to ridge lines takes place.)

The largest landslide of the 1997-1998 El Nino rainfall season took place on Big Creek, some distance above the lower falls. This landslide was approximately 300 feet wide and 350 feet long and, at its deepest was approximately 15 feet deep. It was located on a very steep slope (roughly 45 degrees). The evacuated material consisted of highly weathered quartz diorite (a granitic rock) and surface soil. The site formed a slight descending swale on the slope and probably had experienced previous landsliding some time(s) in the past. It is not clear whether the slide (1) originated at its upslope extremity and moved down to the creek, incorporating more material as it slid/flowed, or (2) the creek cut the slope's toe and this initiated the landsliding which then migrated upslope. (3) The sliding also could have originated in midslope, with subsequent headward migration as well as downslope movement.

In any case, much landslide debris (approximately 20,000 cubic yards) swept down Big Creek. Yet, there is still approximately 20,000 cubic yards of unstable material perched on the lower part of the landslide face. Adjacent slopes immediately to the north (upstream) of the failure site also appear unstable. More landsliding will occur here – in the foreseeable future. No human activity was implicated as causative of the landsliding. This landsliding is consistent with what can be expected in the watershed.

Other relatively large landslides took place on Big Creek, at the lower falls (west slope) and above the old power house (east slope). All were in weathered granitic rock. These larger slides all delivered sediment to Big Creek, but did not dam the creek. Numerous smaller landslides were noted along Big Creek – in granitic and mudstone rocks and old landslide deposits (as by the fish hatchery). Some of these slides were very surficial, 1 to 3 feet thick and mainly of surface soil, especially failures on old creek banks. Surprisingly few slides actually delivered much sediment to the creek, even if they descended nearly to the creek. These Big Creek slides may be somewhat representative of the watershed as a whole, but we found landsliding in each subdrainage of the watershed to differ in some ways. An example would be that landslides were not overall abundant in Little Creek (while the rocks are similar to those on Big Creek), whereas that drainage reportedly experienced abundant and very destructive landsliding in 1955.

Several 1998 El Nino slides were noted on and upslope of the main stem of Scotts Creek. Other slides on Swanton Road cuts and from across a small canyon from Swanton Road, coalesced to flow down to the main canyon of Scotts Creek, a short distance upstream from where Swanton Road crosses the creek. There were slides on the east side slope of Mill Creek. Other subwatersheds experienced sliding as well. Locally, high volume creek flows undercut banks and some bank failures took place, as large volumes of sediment were transported.

These examples illustrate landsliding in the watershed in a time frame of concern, relative to sediment in the creeks and its negative impacts on Coho/anadromous fish (and other organisms). A number of the landslides we observed on the ground are depicted graphically herewith, accompanied by a landslide inventory sheet for each landslide. (*Figure 8*)

Mitigation

We have considered various traditional forms of mitigation to prevent landslide debris from entering the creeks and developed several new methods. Where landslides have already taken place, either much of the debris has already entered the creeks and/or it has deposited on or at the toes of the slides. In the latter case, it would sometimes be possible to excavate perched debris, to revegetate it to hold it in place, and/or to place silt fences or other barriers at the slope bases to hold back the debris (especially as water drained out of the debris and it became more stable). Yet, in most cases, this approach either does not appear necessary or it is not feasible. Revegetation is already underway and water drains out over time. The scale of "repairs" which may be needed is often too great to undertake and access is often very difficult. There are a few cases where concern for reactivation of perched materials by subsequent rainfall events may be sufficient to warrant more detailed consideration of this type of mitigation, on a case-by-case basis.

The matter of scale is important. With the largest Big Creek landslide, some work could be done at and near the toe. Yet, much of the landslide debris already went down the creek at the time of the landslide, with much of it deposited in the Big Creek bed downstream. Further, access to this site is difficult. Then, considering the adjacent unstable-appearing slopes, there is no obvious action which could be taken to prevent this landsliding. The same is true at the sites of the other larger El Nino landslides along Big Creek (See below for mitigation). Many smaller slides where debris currently is perched appear capable of delivering too little sediment to make a significant difference.

With the main stem of Scotts Creek, the lower valley bottom is wide enough that debris entering from side canyons and side slopes at least largely is deposited before reaching the creek. Often, even a relatively small, gently sloping area between the base of a steep slope and the creek itself (such as an old creek terrace) is sufficient to trap the landslide debris. This can be seen at some sites along Little Creek. At some such locations, if landslding, especially debris flows, can be expected regularly, berms could be constructed to hold debris back from creeks.

We also recommend creek bank repair and reestablishment at the site of the railroad track collapse on Scotts Creek. A fallen alder diverted the creek up against the bank during El Nino. This is causing the creek to eat away at the toe of an old landslide deposit which constitutes the bank and slope here. If this landslide were to reactivate, a large volume of sediment would enter the creek here.

It has been determined that there is a (new) proactive method of mitigation which may achieve the desired result of preventing at least some future (critical) landslide sediment from filling the creek beds on Big Creek and perhaps other creeks. This is to effect capture of the sediment at appropriate sites in the creeks downstream from potential landslides. Sediment catchment basins can be excavated in the creek beds. Then pulses

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

DATE ______________________________

REPORT PREPARED BY ______________________________

SLIDE NAME ______________________________

SITE
LOCATION ______________________________

YEAR/HISTORY ______________________________

NATURE OF MATERIAL
SOIL ______________________________
BEDROCK ______________________________
VEGETATION ______________________________

SLIDE
TYPE ______________________________

SIZE/DIMENSIONS ______________________________

ESTIMATED
VOLUME ______________________________

% OF VOLUME IN
CREEK ______________________________

PROXIMITY TO ROADS, DISTURBANCE &/OR OTHER FEATURE & WHAT
TYPE ______________________________

(Thank you to the DFG and SB271 for funding the production and design of this form)

FIG.
8

of sediment will be trapped and can be removed by reexcavation. (Unavoidably, landslides over certain volumes would, however, more than fill the proposed basins.) This sediment trapping would keep fish spawning reaches or stretches of the creeks in suitable condition for fish much or significantly more of the time. On Big Creek, one such site would be in the vicinity of the old power house, downstream of it, in order to capture sediment from the potential upstream landslides, including the powerhouse area. One or more sites could be located on Mill Creek, Scotts Creek above the Swanton Road crossing, Little Creek, and the other feeder creeks of the watershed which are reached by migrant fish. We believe this approach offers much mitigation and protection to the fishery.

In addition, the constructed basins could have their downstream lips dam-like. This would allow retention of water in the ponds at times of low creek water. This, then, would provide some habitat for fish at low water times. Such a plan would be consistent with the Scotts Creek Watershed Council's emergency management plan developed (with the aid of our Technical Advisory Committee – member geohydrologist Barry Hecht) to aid fish survival in the then-impending drought prior to the rainfall (beginning early February) of winter 1997-98.

Another proactive approach we have developed is a form of creek bank protection. Creek bank failure (in addition to upslope landslides) delivers much sediment to the creeks. Often bank failure is caused by collapse of destabilized and leaning alders growing on the banks. Alders are abundant. For example, a roughly 100 foot long section of bank a short distance upstream from Swanton-Pacific Ranch's main buildings was widened by up to approximately 50 feet in El Nino, causing a large volume of alluvial sediment to enter the creek. We propose to identify unstable alders in order to use them to create intstream habitat and to mitigate high potential stream bank failure. This has been considered in another grant proposal.

In conclusion, there is little we can do to prevent the naturally occurring slope failures (landslides, debris flows) which characterize this watershed, though we can prevent some creek bank failures. Therefore, the SCWC proposes the following specific remediation to control sediment input in the stream system. See *Figure 9* for site location map.

PRIORITY MITIGATION PROJECTS FOR SLIDES AND EROSION SOURCES:

<u>Westside of Swanton valley at site of RR track damage, site number SC4.</u>

Creek diversion toward this hillside will continue to eat away the base of this slope causing more landsliding and sediment input. Easy accessibility, landowner support, involvement and expert knowledge and fisheries benefit make this a high priority site. This project involves engineered armouring of the slope toe. This is a possible partnership project with Cal Poly's engineering department.

<u>Steep slide on Swanton Road curve, site number SC6.</u>

This slide has the potential of dumping several hundred cubic yards of fine sediment into the main stem of Scotts Creek. It is also very likely to result in the loss of Swanton Road if substantial repair/mitigation is not undertaken in the near future. This is a priority site because of the potential to resolve a problem that will affect both humans and fisheries if left unfixed and to benefit both if repaired. Appropriate mitigation is envisioned as a

MAP. Slide Inventory Sites
Map too large to scan

combination of rock armouring, gabion structures, with in-creek habitat enhancing structures anchored in.

Swanton Road 4.5 mile marker, site number SC11.
This slumping of fine grained sediments into a high velocity class three drainage is degrading fish habitat on the main stem of Scotts Creek. The site has the potential of dumping approximately 200 cubic yards of fine sediments into the creek and destroying Swanton Road. Simple treatment, easy accessibility, great fisheries benefit and human benefit makes this a high priority project site. Erosion and slumping at this site could be stopped through the use rock armouring in conjunction with biotechnical soil stabilization techniques including planting.

Large slides on Big Creek site numbers BC1 and BC2
Landsliding in this area has the potential to input very large quantities of sand and silt into fish spawning habitat. Fisheries benefit, easy accessibility and landowner support all make the Sediment Containment Basin a priority project. The project could be located near the Power House site. The basin would be created by construction of a boulder and concrete armored earth dam with fish passage structure included. Periodic removal of sediment from basin would be needed to ensure long term efficacy.

Mill Creek picnic site, number MC2
Continued movement of this slide has the potential to dump several hundred cubic yards more sediment into Mill Creek. The weight of a clump of redwood trees has already begun to move more soil down hill and this perched mass of soil will eventually end up in the creek. Site accessibility, landowner support and ease of treatment makes this a priority project.

Alder Management, entire length of Scotts Creek and tributaries
As the mature 50+ year old Alders (approximately 12" plus diameter x 40' plus height) continue to fail, the soil associated with them will be added to the stream system in the form of fine sediment. The time to mitigate this natural occurrence is now before the entire watershed is completely cleared of this large overstory tree. Immediate benefit to fisheries, humans, cost effectiveness, ease of mitigation and landowner support makes this a priority project.

ROAD INVENTORY

The Process

The road inventory portion of this grant was carried out utilizing the procedures and methods developed by Pacific Watershed Associates, Arcata, California. Training of personnel conducting the inventory and analysis was carried out in the Scotts Creek Watershed in January, 1999 by Danny Hagans of Pacific Watershed Associates. The lead person on the road inventory also completed the California Department of Fish and Game Watershed Academy in 1998 in Santa Cruz County.

A road construction history map was constructed for the Scotts Creek Watershed using the sets of aerial photographs from 1928, 1956, 1974, and 1994. As the road inventory was proceeding with field surveys, the age of the road was recorded. This allows for a better understanding of the types of road installations, especially stream crossings that might be encountered in the survey. A summary of the findings of the road construction

Check?___

PWA ROAD INVENTORY DATA FORM (97FULLER VERSION)

ASAP?

GENERAL INFO. Site #: GPS coord: Watershed: Photo: T/R/S:
Road: Mileage: Maintained(Y): Abandoned(Y): Driveable(Y
Inspector(s): Date: Year built: Sketch?(Y):
Treat? (Y,N): Upgrade?(Y): Decommission?(Y):

PROBLEM (circle)- Landslide (fillslope, cutbank or hillslope) Stream crossing Gully
Road bed (rd surface, ditch, cutbank) Ditch Relief CMP Other

Landslide - road fill failure: landing fill failure: deep-seated landslide:
cutbank slide: already failed: potential failure:
dist. to stream (ft): slope(%):

Stream - culvert (Y): bridge (Y): Humboldt (log)(Y): fill (Y): ditch/rd length (ft) - L:
pipe diameter (in): pipe condition (O,C,R,P) ——> inlet: outlet: bottom:
headwall hgt(in): cmp slope(%): stream class(1,2,3): rustline(in) - inlet: outlet:
% washed out: D.P. (Y, N): diverted (Y,N)?: plug potential (H,M,L):
channel grad(%): channel dimensions W: D: sed. transport (H,M,L):

Fish - Outlet drop(ft) - at time of survey: at bankful: Max step hgt. below cmp outlet(ft):
Outlet pool dimensions (ft) - at time of survey - L: D: Pool at bankful flow - L: D:

Erosion - Erosion Potential (H,M,L): POTENTIAL EXTREME EROSION (Y,N): VOL(YD³):
Past erosion (field-yds): Delivery (%): Size W: D: L:
Future eros (field-yds): Delivery (%): Size W: D: L:

Comment on problem - ______________________________

SOLUTION Treatment immediacy (H,M,L): Complexity (H,M,L): Mulch area (ft²):

Treatment-
excavate soil(Y): install critical dip(Y): install ford(Y): sill hgt: width:
add TR/DS(Y): (ft): repair/clean cmp (Y): install/repl cmp (Y): (dia.): (ft):
reconst. fill (Y): armor fill face (Y) - up/down: (ft²):
clean or cut ditch (Y): (ft): *outslope rd (Y): (ft):* *rolling dips (Y): (#):*
remove berm(Y): (ft): *inslope road (Y): (ft):* *rock surface (Y): (ft):*
check cmp size (Y): other (Y): none (Y): INSTALL DRC (Y): (#,

Tot vol excav (field-yds): Vol put back in (yds): Vol removed (yds):
Vol stockpiled (yds): Volume endhauled (yds): Exc prod rate (yds/hr):

Hours- excavator: dozer: dump truck: grader:
loader: backhoe labor: other:

Comment on treatment: ______________________________

history for the road inventory is presented in Figure 3. The roads were field inventoried for past erosion and sediment delivery, including road and landing fill slope failures, stream crossing failures, stream diversion gullies, and sites of road surface and ditch erosion. Field crews followed erosion features downslope to determine dimensions and past sediment delivery.

The inventory of sediment sources from roads also included information on future potential erosion and sediment delivery from the road system. Information included in the survey was only for sites that had the potential to deliver sediment to streams in the watershed. If the problem identified would not result in delivery, then it was not included as an inventory site. Sites such as these were recorded in a maintenance log and this information was delivered to the property owner or land manager for their maintenance planning. The lack of cutbank failure data in the inventory is explained by this, since most cutbank failures were contained by the road and did not or would not result in sediment delivery to streams.

For each inventory site an inventory form was filled out which included a variety of site information. An example of the inventory form utilized is included as *Figure 10.* Each stream crossing was included in the inventory, since any sediment production at stream crossing sites ends up in a stream. Most of the stream crossings in the inventory were fords, culverts or bridges. Special considerations were made for crossings on fish bearing streams to look for factors affecting fish, including fish migration barriers. The potential for stream diversion was considered at each stream crossing along with the potential for plugging and outlet erosion. The field measurements at stream crossings included stream profiles and cross sections which were utilized in the office to calculate the volume of fill in the crossing and to estimate the volume that would have to be excavated to decommission or upgrade a stream crossing for storm proofing. Road surface and ditch contributions to stream crossings were determined by measuring the length of the inslope ditch that fed to the crossing inlet. If the inventory site was a landslide, such as an unstable fill slope, the volume of unstable fill was measured. The distance to the stream and the potential delivery to the stream was determined in the field. Any site that resulted in delivery greater than 5 cubic yards of sediment was included as an inventory site.

The likelihood of potential erosion, erosion and delivery volumes, recommended treatments, equipment and labor needs and treatment priority were recorded for each inventory site. All the inventory data are compiled into a database for the Scotts Creek Watershed, and summaries of the data are included in the implementation plan for road related erosion prevention and erosion control. The complete set of field inventory data is included as Appendix A.

No attempt was made to try to estimate the fine sediment production and delivery to streams associated with surface and rill erosion on roads and landings in the Scotts Creek Watershed. However, there were some recommendations made in the report to reduce fine sediment delivery to streams. The large number of landslides, inner gorge stream side landslides and creek bank failures that delivered sediment to streams appear to account for the majority of the sediment production in the watershed.

Findings

The road inventory field work was completed over a period of approximately one year, beginning with the training by Pacific Watershed Associates in February, 1999 and concluding in early March, 2000. In addition to the field work, much office work is necessary to complete the calculations for excavations, equipment and labor requirements, summarization of erosion past and future, and prioritization of sites or remediation.

A total of 162 inventory sites were identified on the 37.5 miles of road surveyed in the Scotts Creek Watershed. These sites are identified on the map in *Figure 11*. Four methods of sediment production from roads were included as part of the methodology from Pacific Watershed Associates. Those were 1) stream crossings from fluvial processes involving crossing failure and diversion, 2) landslides including fillslope, cutbank and hillslope slides associated with roads, 3) gullies resulting from ditch relief culverts or failures of inslope ditches 4) sediment from ditch and road runoff and 5) ditch relief culverts. The results of the findings from the inventory are summarized by sediment source in Table 6. Strategies and techniques for storm proofing and for sediment reduction were recommended for each of these five methods of production.

Table Six. Sites of Future Road Related Sediment Delivery

Source	Number of Sites	Sites to be Treated	Est Future Sediment
Stream Crossings	106	81	7010
Landslides	30	26	18771
Gullies	4	2	0
Ditch and Road	11	10	818
Ditch Relief Culvert	11	8	293
Totals	162	127	26892

Stream Crossings

A total of 106 stream crossings were inventoried in the road assessment for Scotts Creek Watershed. This represents 65.4 percent of the total inventory sites. These crossings were predominantly of three types: culverts, bridges, and fords. There were some older crossings that had washed out that were Humboldt crossings. No maintained and in use roads had Humboldt crossings. The crossings that were included in the inventory consisted of 65 culverts, 10 bridges,2 Humboldt crossings, and 29 fords. Most of the fords are found on roads that are not in regular use and are maintained for emergency access or trails for hiking or equestrian use or are not maintained. The fords are generally located on small class 3 streams. Some of these sites have evidence of active sediment production and most need to be treated to prevent future sediment production. Table 7 shows the potential reduction in future sediment production from stream crossings if the recommended treatments are implemented.

Table Seven. Stream Crossing Related Sediment Reduction by Subwatershed

Subwatershed	Number of Sites	Estimated Sediment Reduction
Queseria	4	109
Archibald	4	6627
Winter	3	261

MAP: Road Inventory Sites Scotts Creek
Map too large to scan

Little	10	489
Big	1	0
Mill	37	1802
Boyer	39	4978
Scotts	8	14611
Total	106	14611

Most of the sediment production at stream crossings comes from events such as stream flows exceeding culvert capacitiv or plugged culverts and bridges which often result in diversion of the stream down a road or into an area where a new gully is formed. The stream crossings in the inventory identified 62 crossings with the potential for diversion and 17 of those were diverted at the time of the survey. Evidence of p[illegible] found at many more stream crossings. This situation can often be remedied by installing a critical dip to put the water back into the original channel. There were 40 stream crossings where a critical dip was recommended. Stream diversion is one source of potential extreme erosion, and 20 stream crossings had the potential for extreme erosion.

Culvert sizing is an issue on most of the roads that were inventoried. Field estimates were made for streams that were too small to be observed on the USGS Quadrangle maps. These were done by observing the cross sectional area of the active stream channel at bankfull flow levels above the stream crossing. An area was calculated and the size of culvert required to provide that cross sectional capacity was recommended for installation. Table 8 provides the cross sectional area of culverts by diameter. The field estimate method does not always provide accurate information on the size of culvert necessary to handle peak flows. Current standards require that culverts be sized for flow resulting from a 50-year rainfall event. Where possible the rational method was utilized to provide a better indication of the size of culvert recommended to handle the 50-year storm event flow. A part of the office work involves determining the recommended culvert sizes for stream crossings where culverts are used to pass the water through the road prism.

Table Eight: Cross Sectional Area of Culverts by Diameter

DIAMETER	AREA IN SQ FT
12	0.8
18	1.8
24	3.1
30	4.9
36	7.1
42	9.6
48	12.6
54	15.9
60	19.7
66	23.8
72	28.3

For stream crossings with culverts where the drainage is identifiable on the 7 1/2 minute quadrangle maps (scale 1"=2000'), the rational method was used to size the culverts for a 50-year storm. The storm intensities were determined from the 50-year storm intensity maps for California. These maps (Appendix Two) are produced by the California Department of Conservation and must take into account the time of concentration of flow in the watersheds.

The rainfall intensity for the Scotts Creek Watershed was determined from the 50-year storm intensity maps for storms from 15 minutes to 12 hours. That data is included in Table 9.

Table Nine. Rainfall Intensity for 50-Year Storms

Duration	Amount in Minutes
15 min	3.0
30 min	2.2
60 min	1.8
120 min	1.4
180 min	1.2
360 min	1.0
720 min	0.7
1440 min	0.4

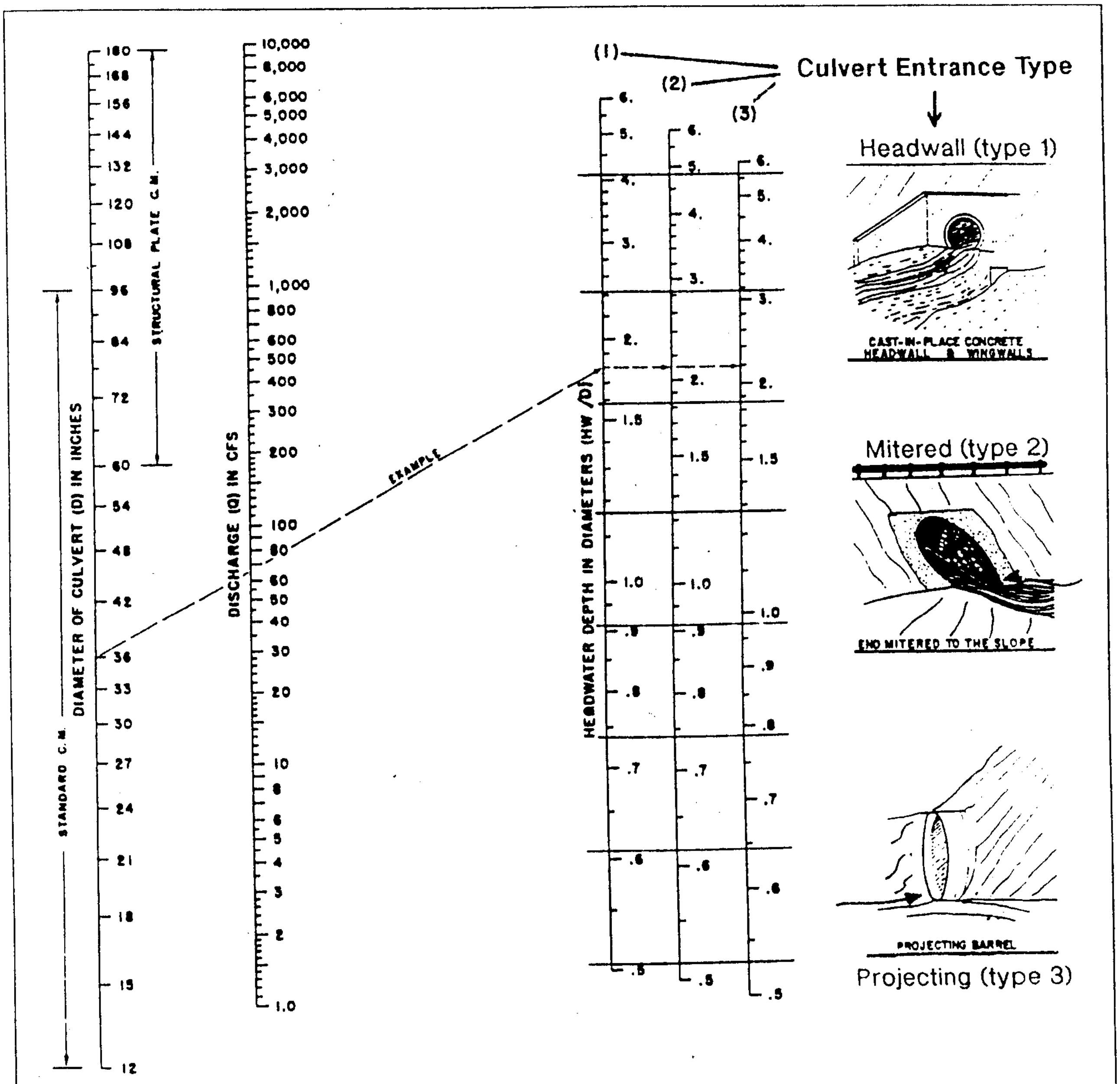
The time of concentration is determined from the length of the stream and the elevational change in the stream in the area of consideration. The time of concentration is used to select the proper map for determining the rainfall intensity. This is then used with the area of the watershed and the runoff coefficient to determine the flow in cubic feet per second that must be accommodated in the culvert. This number was used with a culvert nomograph (*Figure 12*) assuming headwall size no less than 1.5 times the diameter of the culvert. The rational method was used for a total of 14 drainages (Figure 12) to determine the appropriate sizes of culverts to accommodate the 50-year storm flow. The calculations are shown in Table Eight. From these calculations it was determined that most of the culverts in place in the watershed at stream crossings are undersized for the 50-year storm flow. In addition many of these have a high plug potential due to debris flow events associated with intense rainfall in the area. Numerous problems have been encountered in the watershed at these crossing in the February, 1998 and February, 2000 storms. All of these sites are high priority for culvert upgrading to try to prevent future plugging and erosion due to loss of fill or diversion.

The culvert size is determined by calculating a Q value for the stream from the following formula.

$Q = CIA$

- Q = Peak runoff at the stream crossing
- C = Runoff Coefficient
- I = Uniform Rate of Rainfall Intensity (Inches/Hour)
- A = Area of the Drainage (Acres)

Step 2: Using the Culvert Capacity Nomograph to determine needed culvert size



1. Determine the "entrance type" from the sketches above.
2. Calculate the expected "Headwater Depth" in **diameters** from field measurements (e.g., a 36 inch culvert whose <u>bottom</u> will be 8 feet below the lowest point on the road grade over the crossing has a headwater depth of 8 feet, or 2.7 culvert-diameters (8ft./3 ft. = 2.7).
3. Place a straight edge connecting the Headwater Diameter scale (right side of nomograph) through the calculated 50-year flood discharge (from the Rational Method, in this example).
4. Read off the needed culvert diameter on the left scale of the nomograph.
5. In the example, the Headwater Depth for a Type 1 entrance (1.8), Type 2 entrance (2.1) or a Type 3 entrance (2.2) culvert to be installed on a small stream with a calculated 50-year flood discharge of 66 cubic feet per second would require a 36-inch diameter culvert.

FIG. 17

The runoff coefficient is determined based on the land use, soils, and vegetation of the drainage. There are several sources of this coefficient. For this inventory a value of 0.30 was utilized. The following table from th "Handbook for Forest and Ranch Roads" provides a range of C values for different rural areas.

Table 10. C Values for Rural Areas

Soil Conditions	Land Use	C Value
Sandy and Gravelly Soils	Cultivated	0.20
	Pasture	0.15
	Woodland	0.10
Loams and similar soils	Cultivated	0.40
without impeded horizons	Pasture	0.35
	Woodland	0.30
Heavy clay soil or those	Cultivated	0.50
With shallow impeding	Pature	0.45
Horizon: shallow on bedrock	Woodland	0.40

The uniform rate of rainfall intensity must be calculated using the following formula.

$Tc = (0.0078L^{0.77})/(H/L)^{0.385}$

Tc = Time of concentration
L = Maximum distance along stream to most distant redgetop (Feet)
H = Elevation difference along the maximum stream pathway (Feet)

The rational method calculations and the recommended culvert size and headwall height for the installations are included in *Table 13*.

Table thirteen. Rational Method Culvert Size Calculations

Winter at
Haul Road

A = 65.24 Tc = 0.49268252 hours I = 2.2
8

L = 4090.0 29.5609516 min
0 8

H = 235.00

Q = 43.06

Existing Headwall
Height = 140
inches
Culvert Headwall Height = 54"
Size = 36"

Winter at
Swanton

A =	144.48	Tc =	0.55351343 hours 3	I =	2.14
L =	5910.0 0		33.2108059 min 6		
H =	320.00				
Q =	92.76				

Existing Headwall
Height = 60
inches
Culvert
Size = 48"

Headwall Height = 72"

Archibald at Haul Road

A =	405.34	Tc =	1.41044627 hours 2	I =	1.62
L =	9300.0 0		84.6267763 min 3		
H =	212.00				
Q =	197.00				

Existing Headwall
Height = 48
inches
Culvert
Size = 60"

Headwall Height = 90"

Archibald at Swanton

A =	421.38	Tc =	0.81213974 hours 8	I =	1.95
L =	10100. 00		48.7283848 min 6		
H =	405.00				
Q =	246.51				

Existing Headwall
Height = 60
inches
Culvert
Size = 60"

Headwall Height = 90"

Scout Camp

A =	162.70	Tc =	0.66377521 hours 8	I =	2.04
L =	6635.0 0		39.8265131 min		
H =	305.00				
Q =	99.57				

Existing Headwall
Height = inches
Culvert
Size = 48"

Headwall Height = 72"

Scott's #1

A =	45.22	Tc =	0.34383370 hours 8	I =	2.65
L =	3215.0 0		20.6300224 min 9		
H =	255.00				

Q = 35.95

Existing Headwall
Height = 20
inches
Culvert Headwall Height = 54"
Size = 36"

Table 10. Continued

Canfield at
Swanton

A = 38.02 Tc = 0.44405191 hours I = 2.33
1
L = 4080.0 26.6431146 min
0 4
H = 260.00

Q = 26.58

Existing Headwall
Height = 78
inches
Culvert Headwall Height = 78"
Size = 36"

McDougal at Swanton

A = 97.87 Tc = 0.68391074 hours I = 2.02
3
L = 5930.0 41.0346445 min
0 6
H = 260.00

Q = 59.31

Existing Headwall
Height = 102
inches
Culvert Headwall Height = 80"
Size = 36"

Las Trancas at Swanton

A = 74.77 Tc = 0.48301125 hours I = 2.23
L = 4315.0 28.9806750 min
0 1
H = 255.00

Q = 50.02

Existing Headwall
Height = 94
inches
Culvert Headwall Height = 90"
Size = 30"

No Name Draw at
Swanton

A = 56.22 Tc = 0.48993491 hours I = 2.23
6
L = 3950.0 29.3960949 min
0 4
H = 227.00

Q = 37.61

Existing Headwall
Height = inches
Culvert Headwall Height = 45"
Size = 30"

OK Corral at Swanton

A =	39.31	Tc =	0.49561601 hours 7	I =	2.2
L =	2995.0 0		29.7369610 min 2		
H =	163.00				
Q =	25.94				

Existing Headwall
Height = inches
Culvert Headwall Height = 45"
Size = 30"

Queseria at Swanton

A =	378.00	Tc =	0.73853856 hours	I =	1.98
L =	8340.0 0		44.3123135 min 8		
H =	357.00				
Q =	224.53				

Existing Headwall
Height = 72
inches
Culvert Headwall Height = 99"
Size = 66"

Tischler at
Swanton

A =	32.70	Tc =	0.40910873 hours 9	I =	1.98
L =	3002.0 0		24.5465243 min 6		
H =	198.00				
Q =	19.42				

Existing Headwall
Height = 72
inches
Culvert Headwall Height = 45"
Size = 30"

Road Related Landslides

Out of the 162 sites,30 of them were road related landslide problems. Most of these were fillslope failures. Many of these are related to the past maintenance practice of sidecasting while grading the road. This has produced an accumulation of uncompacted fill on the outer edge of the road prism. These uncompacted accumulations are very prone to sliding, especially if they are saturated from precipitation or water from the road surface. Another factor observed is the relationship to trees which have grown on the fillslope since road construction. In Little Creek a record was kept of cutbank and fillslope failures, there were 14 slides in 2.5 miles of road. Of these 14 slides, 7 or 50 percent were tree failure related. From this small study, it is apparent that managing trees that occur on unstable fillslopes and cutbanks can greatly reduce the rate of failure.

This should become an important part of the road maintenance program. Left untreated, the landslides have the potential to deliver many cubic yards of sediment. Deep-seated landslides are often not amenable to cost-effective treatments. These sites need special management and continued observation to reduce sediment production. In some cases roads with deep-seated slides should be considered for rerouting and decommissioning of the abandoned sections.

Treatment of Road Related Sediments

Prioritizing the work to be done can be approached from a variety of ways. Since the watershed is made up of numerous landowners, one approach would be by ownership. This is most likely how the remediation work will be done; however, each owner may need to prioritize work on the land they manage. Methods of prioritizing within ownerships include treatment immediacy, amount of future potential sediment, costs of treatments, and by road. There are cost savings in equipment logistics if the prioritization is done by road. That way the hauling and setup times can be reduced on a per site basis. The road prioritization basis can be used very effectively and roads can be storm proofed based on the other priority methods listed above. Roads in the watershed are listed in Table 12 with a summary of road treatment priorities and volume of future sediment saved.

Table 12. Road Treatment Based on Site Density and Future Delivery

Road	# of Sites	High	Mod-High	Moderate	Est Sediment
6952 Spur	7	1	4	0	2129
Boyer Ck	5	0	1	1	122
Center Ridge	6	0	1	1	167
Center Ridge Spur A	7	2	1	1	9318
Lake	9	1	0	0	3931
Little Ck	13	2	0	4	366
Lower Mill Ck	5	0	3	0	147
Mill Ck Res	7	3	2	1	415
Oak Flat	13	4	1	2	434
Road Spur A	6	0	3	1	191
Upper Boyer Ck	11	4	5	1	2221
Swanton	21	2	4	4	535
Mill Ck	9	3	2	2	407
Haul	5	0	0	1	19
Jerry's	6	0	0	1	49
Totals	118	22	27	20	20151

The road inventory has proven to be a useful project to assist landowners and those charged with road maintenance. The inventory provides an indication of the areas of concern with regard to future sediment production that can enter the streams in the watershed and result in degradation of fish habitat. The treatment immediacy rating provides insight into the priority with which to remediate sites. In addition to the inventory sites, maintenance log books were provided to landowners for work that needs to be done on roads at locations that will not deliver sediment into streams. Table 13 provides a summary of the recommended treatments for the watershed.

Table 13. Recommended Treatments for Scotts Creek Watershed Roads

Treatment	Number of Sites	Treatment	Number of Sites
Critical Dip	48	Armor Fill Face	40
Install CMP	5	Clean/Repair CMP	17
Replace CMP	38	Clean/Cut Ditch	16
Excavate Soil	52	Install DRC	3
Install Downspout	15	Install Rolling Dips	30
Install Ford	18	Remove Berm	4
Rock Road	13	Inslope/outslope Road	13

In addition to the recommendations for treatments, the data provided for each inventory site includes the type of equipment recommended to implement the treatment and the labor requirements to go along with the equipment use. These estimates are summarized by treatment priority in Table 14. Cost estimates for the overall treatment recommendations were not made, since equipment rates and availability vary by landowner and with time. The move-in and move-out expenses are also quite variable depending upon the access and the conditions of the roads over which the equipment must move. If some rough estimates are made using rates of $125 per hour for excavators, $80 per hour for dozers, $60 per hour for dump trucks, and $25 per hour for laborers. Table 14 includes time estimates for onsite work only and do not include set-up and moving time. Estimates for this range as high as 30% of the total time for each category. Using this assumption, the total costs associated with the data in Table 14 would be $35,588 for excavators, $23,400 for the dozers, $4,251 for dump trucks (plus haul time and purchase price for loads of rock), and $7,800 for labor. In addition there must be project supervision to make certain the treatment locations are found and that the recommendations are understood and carried out at the sites. This is estimated at 10 % of the project costs or $7,100. This brings the total project estimate for labor and equipment to approximately $78,000. This estimate does not include supplies such as culverts, rock, seed, geotextile cloth, plant materials

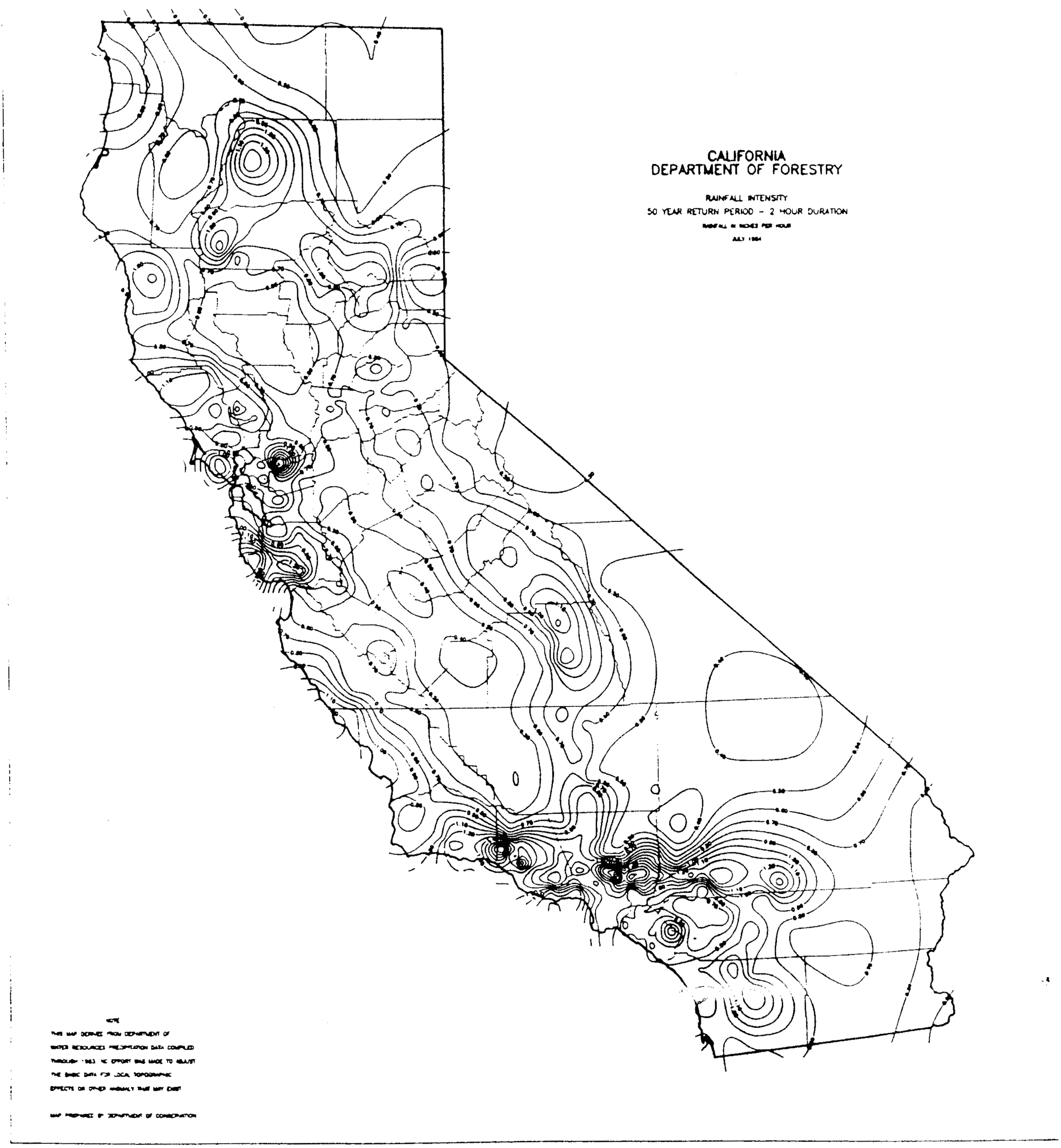
Table 14. Equipment and Labor Requirements for Treatment Recommendations

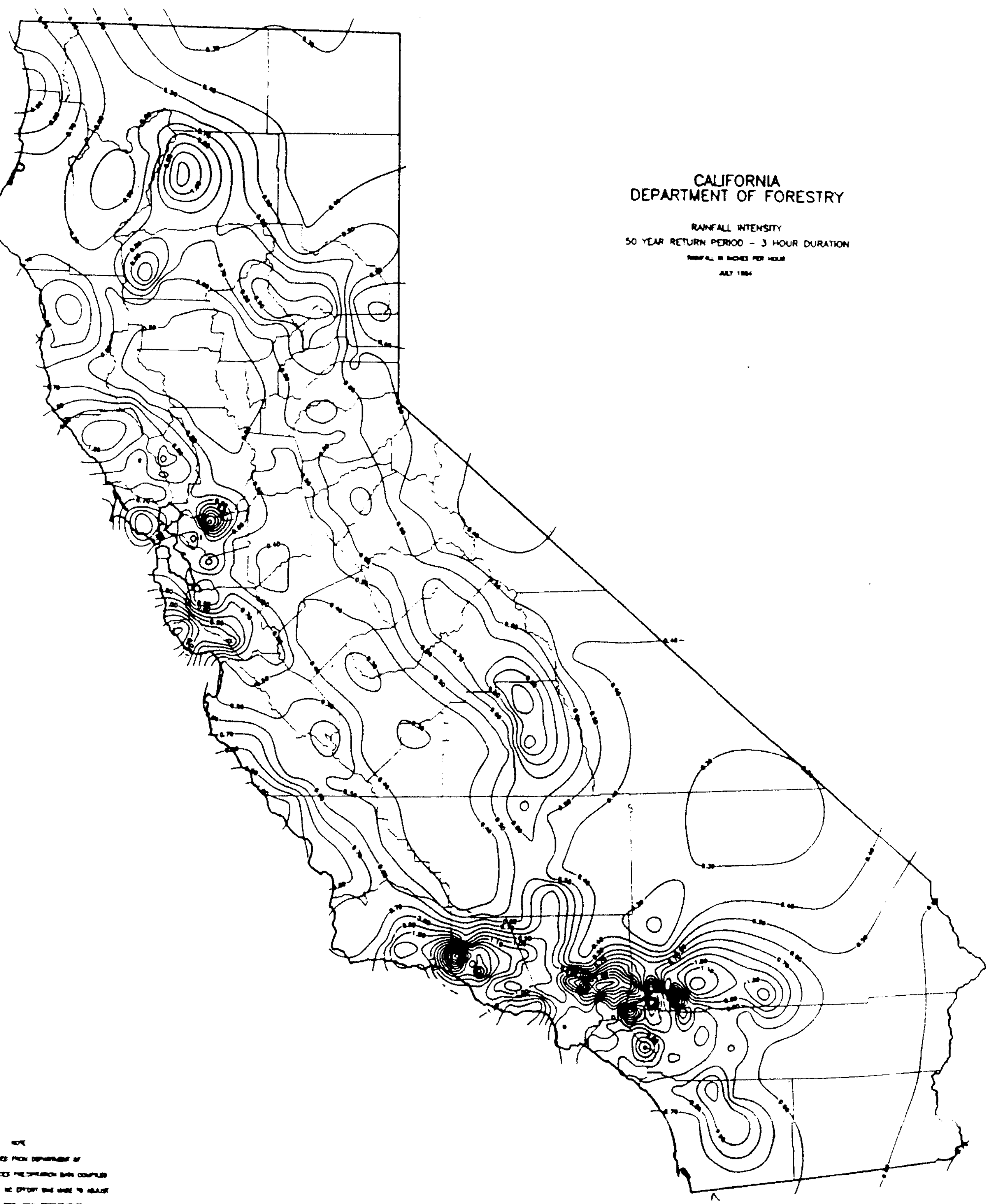
Treatment Priority	# of Sites	Yards Exc	Excavator	Dozer	Dump Truck	Labor
High to Medium-High	57	1779	108.5	134.5	15	110
Medium to Medium-Low	39	2161	70.5	56.5	33	80.5
Low	29	1395	40	34	6.5	49.5
Totals	125	5335	219	225	54.5	240

CONCLUSION

The Roads and Landslide Sediment Source Investigation has allowed the Scotts Creek Watershed Council to identify a great number of sites which may be responsible for depositing an excess of fine sediments into Salmonid habitat. This study has resulted in recommended remediation for numerous sites on both roads and along streams. In addition, sediment sources such as pig wallowing and tree fall along roads (which require further discussion and study) have been identified. Everyone involved in this project has acquired a clearer understanding of the processes at work in the watershed. It is hopeful that the treatments recommended herein will be considered and some of them implemented by the vested parties. It is hopeful that this report will not only serve as a guide and model for residents, landowners and landmanagers, but will also be one of the building blocks for further research and watershed benefits. The Scotts Creek Watershed Council thanks the Department of Fish and Game and the SB 271 grant for funding this project.

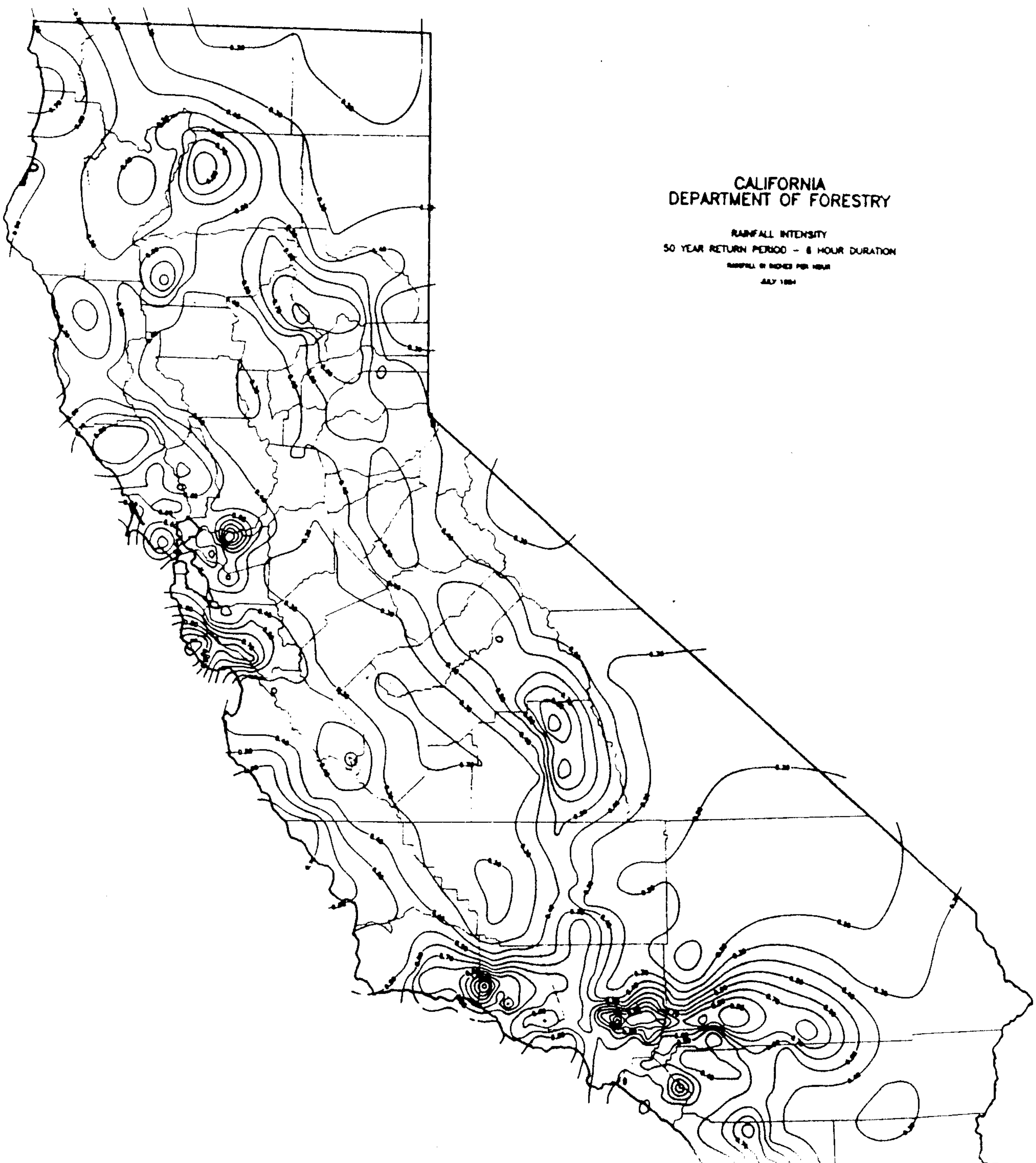
APPENDIX A
California Rainfall Intensity Maps


CALIFORNIA
DEPARTMENT OF FORESTRY
RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 2 HOUR DURATION
RAINFALL IN INCHES PER HOUR
JULY 1964
NOTE
THIS MAP DERIVES FROM DEPARTMENT OF
WATER RESOURCES PRECIPITATION DATA COMPILED
THROUGH 1963. NO EFFORT WAS MADE TO ADJUST
THE BASIC DATA FOR LOCAL TOPOGRAPHIC
EFFECTS OR OTHER ANOMALY THAT MAY EXIST
MAP PREPARED BY DEPARTMENT OF CONSERVATION



CALIFORNIA
DEPARTMENT OF FORESTRY

RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 3 HOUR DURATION

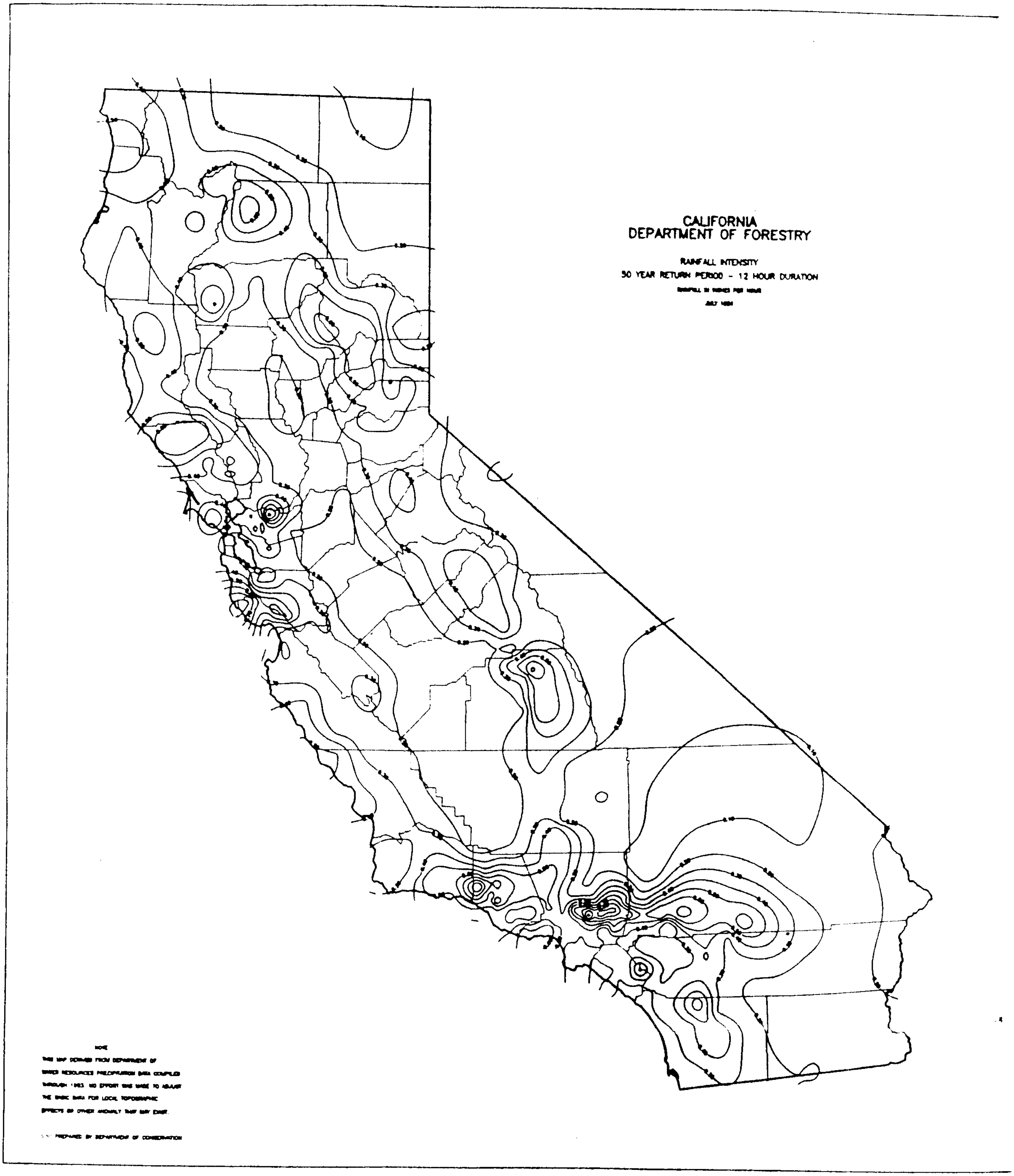


CALIFORNIA
DEPARTMENT OF FORESTRY

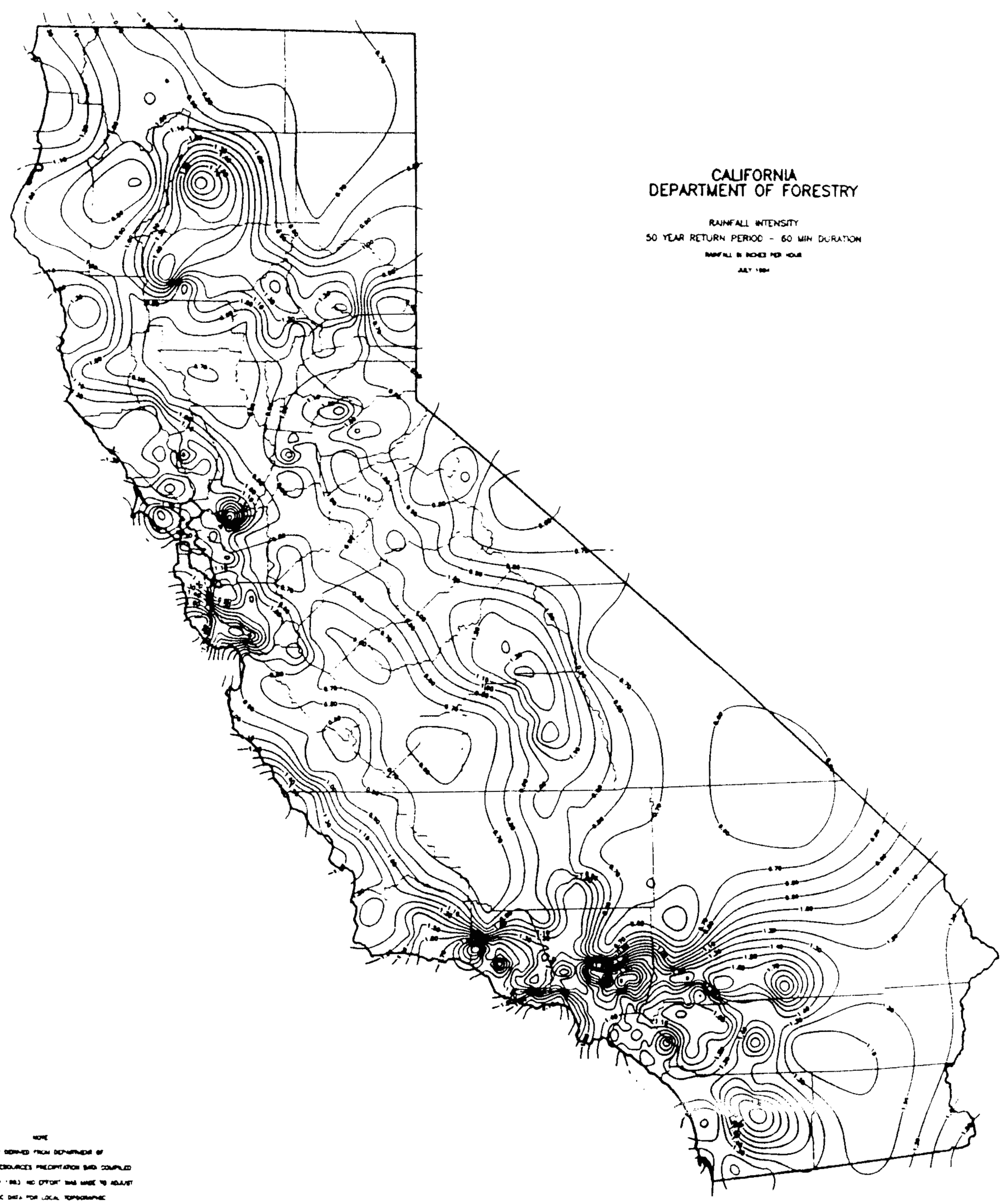
RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 6 HOUR DURATION
RAINFALL IN INCHES PER HOUR
JULY [illegible]

NOTE
THIS MAP DERIVED FROM DEPARTMENT OF
WATER RESOURCES PRECIPITATION DATA COMPILED
THROUGH [illegible] NO EFFORT WAS MADE TO ADJUST
THE BASIC DATA FOR LOCAL TOPOGRAPHIC
EFFECTS OR OTHER ANOMALY THAT MAY EXIST

MAP PREPARED BY DEPARTMENT OF CONSERVATION



CALIFORNIA
DEPARTMENT OF FORESTRY
RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 12 HOUR DURATION

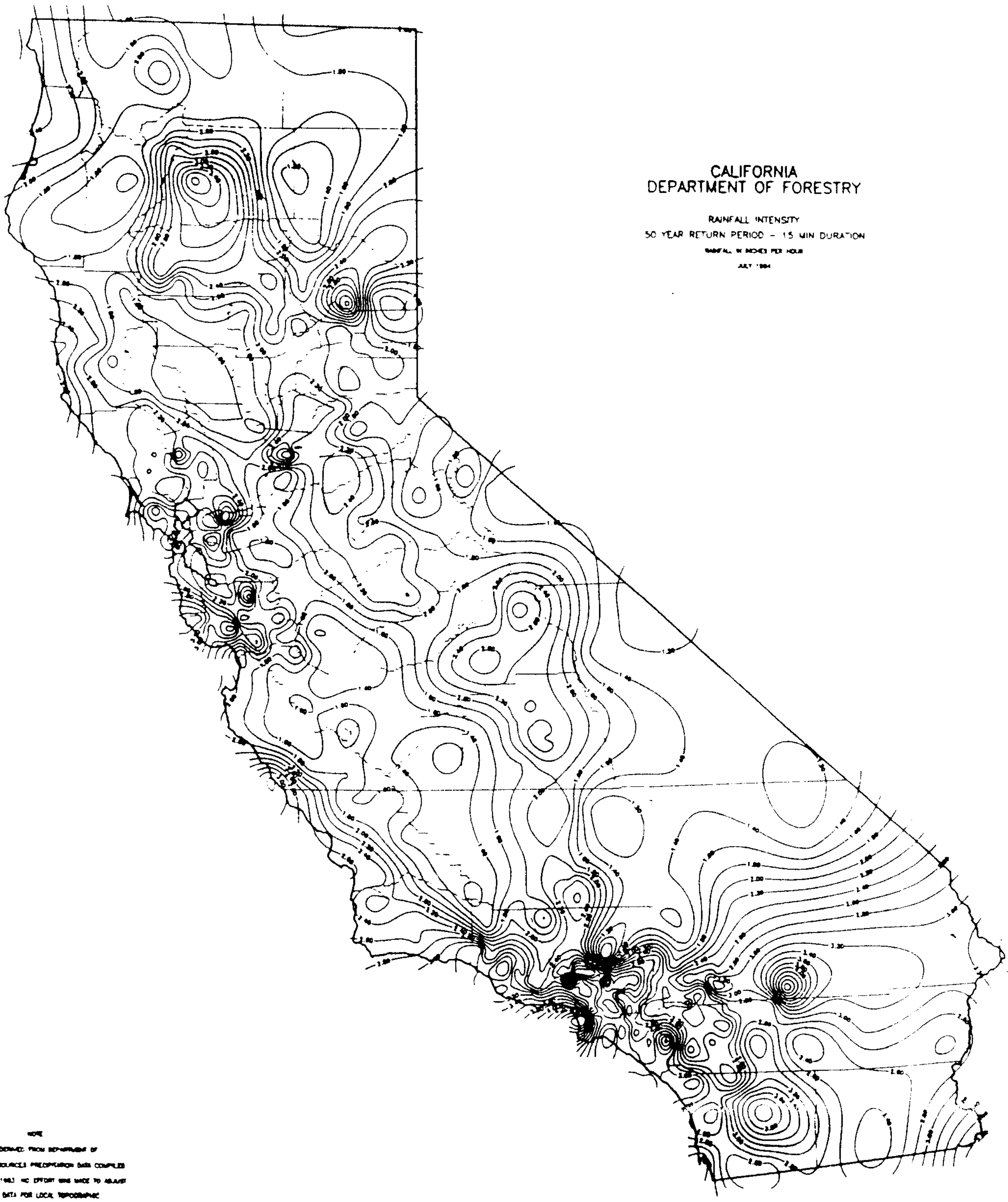


CALIFORNIA
DEPARTMENT OF FORESTRY

RAINFALL INTENSITY
50 YEAR RETURN PERIOD - 60 MIN DURATION
RAINFALL IN INCHES PER HOUR
JULY 1984

NOTE
THIS MAP DERIVED FROM DEPARTMENT OF WATER RESOURCES PRECIPITATION DATA COMPILED THROUGH [illegible]. NO EFFORT WAS MADE TO ADJUST THE BASIC DATA FOR LOCAL TOPOGRAPHIC EFFECTS OR OTHER ANOMALY THAT MAY EXIST

MAP PREPARED BY DEPARTMENT OF CONSERVATION



CALIFORNIA
DEPARTMENT OF FORESTRY

RAINFALL INTENSITY

50 YEAR RETURN PERIOD - 15 MIN DURATION

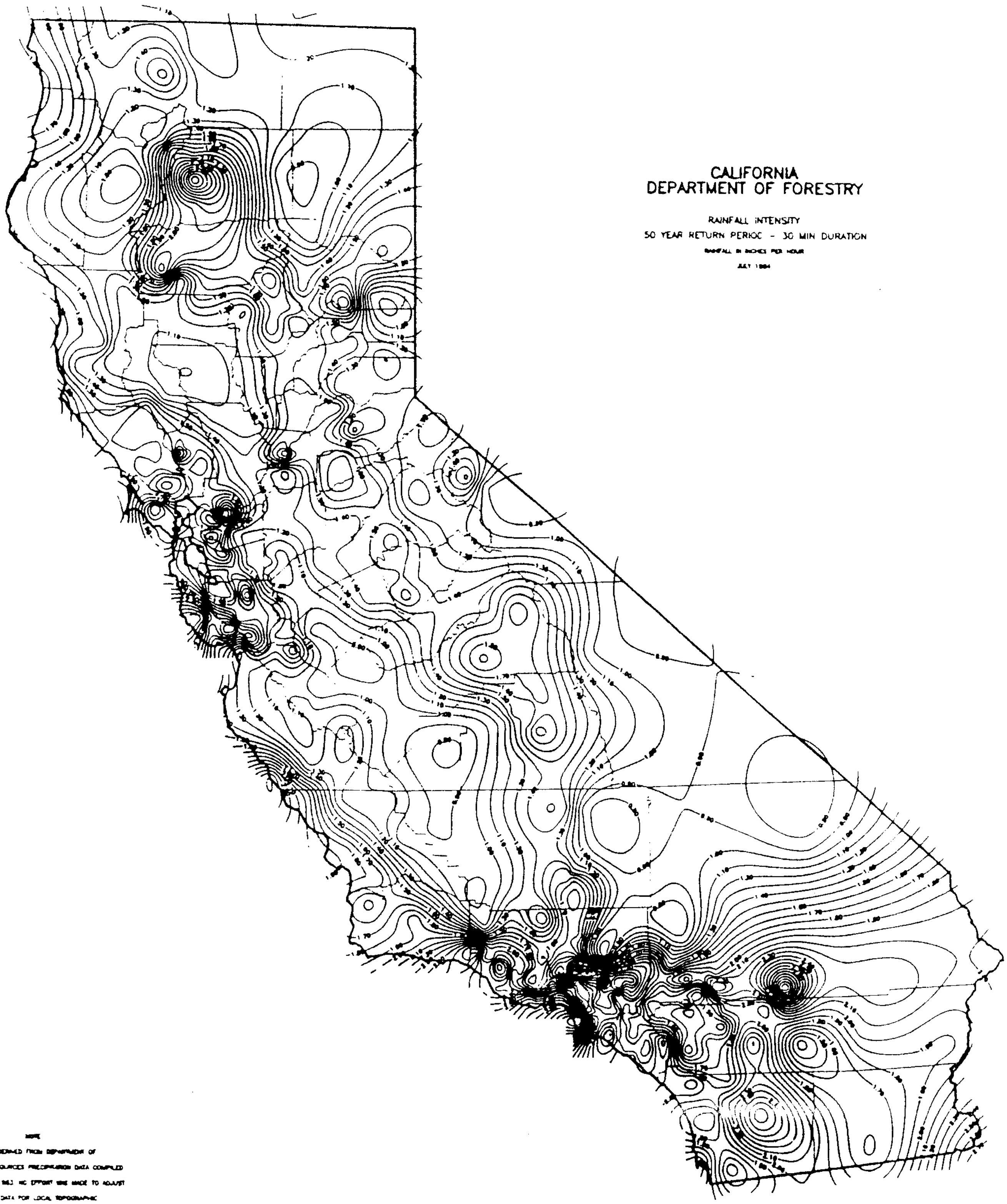
RAINFALL IN INCHES PER HOUR

JULY 1984

NOTE

THIS MAP DERIVED FROM DEPARTMENT OF WATER RESOURCES PRECIPITATION DATA COMPILED THROUGH 1983. NO EFFORT WAS MADE TO ADJUST THE BASIC DATA FOR LOCAL TOPOGRAPHIC EFFECTS OR OTHER ANOMALY THAT MAY EXIST

MAP PREPARED BY DEPARTMENT OF CONSERVATION



CALIFORNIA
DEPARTMENT OF FORESTRY

RAINFALL INTENSITY

50 YEAR RETURN PERIOD - 30 MIN DURATION

RAINFALL IN INCHES PER HOUR

JULY [illegible]

NOTE

THIS MAP DERIVED FROM DEPARTMENT OF
WATER RESOURCES PRECIPITATION DATA COMPILED
THROUGH [illegible]. NO EFFORT WAS MADE TO ADJUST
THE BASIC DATA FOR LOCAL TOPOGRAPHIC
EFFECTS OR OTHER ANOMALY THAT MAY EXIST

MAP PREPARED BY DEPARTMENT OF CONSERVATION

APPENDIX B
Slide Inventory Data Forms

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC1
DATE	September 1999
PREPARED BY	R. K. Smith
SITE LOCATION	Small relatively steep canyon on W. side slope of Swanton Valley near the Valley's S. end
YEAR/HISTORY	Occurred during winter 1996-1997 and 1997-1998
NATURE OF MATERIAL: SOIL	Channel fill and low on slope, alluvial/colluvial fan deposit
BEDROCK	Some weathered, may have been plucked up by debris flow.
VEGETATION TYPE	Brush, some oaks, buckeyes at the base of slope, toe has horse tails and juncas
SLIDE TYPE	Tree uproot with ground saturation caused slump, slip, debris flow
SIZE/DIMENSIONS	Length ? x 3' wide, fan 85' from base at 120 deg. And approx. 6' deep at toe and 4' deep at top of steep fan
ESTIMATED VOLUME	4 cubic yards
% OF VOLUME IN CREEK	NONE
PROXIMITY FEATURE & WHAT TYPE	300 yards from creek. RR. line at base of slope is covered with fan.
NOTES:	Field part of flood plain, hill probably adacent to creek historically

TREATMENT RECOMMENDED:

NONE

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER SC2

DATE September 1999

PREPARED BY R.K.. Smith

SITE NAME S. end Swanton Valley

SITE LOCATION Very steep canyon on east facing slope on W. side of SwantonValley near the valley's S. end

YEAR/HISTORY Occurred during winter 1996-1997 and again, less severely in 1997-1998. Was possibly active 1982.

NATURE OF MATERIAL:

SOIL Thin surface soil, layer of marine terrace deposit slope top, some agricultural soil from field above, some previous channel fill

BEDROCK Very surficial weathered bedrock included in/from steep soil slip area. Possible that some angular rock fragments also came from terrace deposit above.

VEGETATION TYPE Brush, some oaks, buckeyes at the base of slope, toe has horse tails and juncas

SLIDE TYPE Shallow soil slip - flow outward in very slightly incised channel on lower moderate colluvial slope to valley bottom. Formed small alluvial fan of angular bedrock cobbles and pebbles .

SIZE/DIMENSIONS - Slide source - length ? x 30' wide x 1-1/2' deep. Channel 50' long x 1'wide x 1' deep, fan - 50' long x 30' wide x 6" - 8" deep. 1996-97 slide was approx. 1 acre of material 2-3' deep.

ESTIMATED VOLUME 10 cubic yards

% OF VOLUME IN CREEK none

PROXIMITY TO FEATURES & WHAT TYPE 200 yards from creek. RR line at base of slope is covered with fan.

NOTES: Slope descends from marine terrace top to valley floor. Steep, straight single channel, v-shaped, slightly to moderately incised draw. Field part of flood plain, hill probably adjacent to creek historically.

TREATMENT RECOMMENDED
None

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC3
DATE	September 1999
PREPARED BY	R. K. smith
SITE NAME	W. side Swanton Valley
SITE LOCATION	West side of Swanton Valley, opposite CDF station
YEAR/HISTORY	Occurred during winter 1997-1998
NATURE OF MATERIAL	
SOIL	Thin soil on very steep slope
BEDROCK	
VEGETATION TYPE	Brush
DEPOSIT TYPE	Soil slip
SIZE/DIMENSIONS	Three discrete parts or adjacent slides, treated as one: a. 150' long x 30' wide x 1' deep = 80 cubic yards, b. 80' long x 10' wide (at top) 15' wide (below mud stone out crop) x 1-1/2' deep = 50 cubic yards, c. 130 long x 15' wide (at top to right) 10' wide (at top) 15' wide at base x 1-1/2' deep = 60 cubic yards
ESTIMATED VOLUME	190 cubic yards
% OF VOLUME IN CREEK	NONE
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Base of slope is 20 - 30 feet west of RR line. Debris caught behind a low rise in a possible old creek channel.
NOTES:	These 3 adjacent and related soil slips are located within a much larger arcuate slope scar which represents a larger landslide all on the very steep slope segments along the west side of Swanton Valley
TREATMENT RECOMMENDED:	NONE

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC4
DATE	September 1999
PREPARED BY	R. K. smith
SITE NAME	W. side swanton valley
SITE LOCATION	West side of swanton valley, adjacent to Scotts Creek at site of RR track damage.
YEAR/HISTORY	Occurred during winter 1997-1998
NATURE OF MATERIAL	
SOIL	Colluvial and/or landslide deposit
BEDROCK	S. C. mudstone covered by above deposition.
VEGETATION TYPE	Riparian vegetation is gone within site. Bay, Oak, Douglas Fir, Buckeye and scrub above site. Alder and Box Elder adjacent to site.
DEPOSIT TYPE	Bank erosion by creek cutting toe of old translational slide and/or flow deposit.
SIZE/DIMENSIONS	20' wide x 12' long x 10' deep
ESTIMATED VOLUME	88 cubic yards
% OF VOLUME IN CREEK	100%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Edge of creek, along RR line.
NOTES:	This event was caused by Alder fall diverting creek direction toward base of slope and subsequent undercutting. Continued exposure of this bank clearly will result in more erosion of landslide toe and probable reactivation of landslide at some scale.
TREATMENT RECOMMENDED:	Armor slide toe with rock or other engineering structure. Build catch terrace to contain debris from above and encourage slope repose.

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC5
DATE	September 1999
PREPARED BY	R. K. smith
SITE NAME	S. of trestle
SITE LOCATION	Site is 50 yards downstream of Swanton Pacific RR trestle on outer bend of Scotts Creek.
YEAR/HISTORY	This is a prehistorical rotational slump site affected by high water velocity and rain during winter 1997-1998
NATURE OF MATERIAL	
SOIL	Old landslide deposit
BEDROCK	S. C. mudstone with dipping beds.
VEGETATION TYPE	Riparian vegetation adjacent. Immediate site has fallen Alders in remaining debris. Bay, Oak, Douglas Fir, Buckeye and scrub above site.
DEPOSIT TYPE	Bank erosion by creek cutting toe of old translational slide and/or flow deposit. Channel flow debris flow deposit and slump block of mass of older channel fill.
SIZE/DIMENSIONS	Entire site is 184' wide. Upstream wedge site is 60' long x 80' wide x 3' deep. Failed downstream channel fill site is 5' long x 70' wide x 5' deep with a resting debris base 10' long x 80' wide x 10' deep.
ESTIMATED VOLUME	533 cubic yards at upstream site with 266 cubic yards still in place. Down stream site has a total of 361 cubic yards moved with approximately 296 cubic yards still in place.
% OF VOLUME IN CREEK	62%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Adjacent to creek. About 50 yards from RR line
NOTES:	Although, adjacent to creek and oversteepened by some creek cutting, this site has natural erosion tendencies. The upstream site is a wedge fracture formed by two intersecting, steeply dipping fracture planes in an old

NOTES:

mudstone landslide block. This caused a chute on a steep slope(60%) with a talus cone at base of chute. Material at base was not entirely washed away indicating that event was not instigated by creek. Dipping trees in this talus cone are leaning indicating continual movement. The downstream portion of the site is seperated from upstream by an undisturbed soil area still vegetated from before 97-98 event. This area does reveal some dipping mudstone beds which end abruptly at downstream portion of site. Downstream site is an old channel fill composed of debris flow deposit with a slump block mass of older channel fill at base. Weight of vegetation, soil saturation, and composition of more organic, loose material in this channel caused this failure. Heavier debris such as boulders and cobble remain in the slump block. Like the upstream site, oversteepening by creek cutting of toe may have helped instigate this event.

TREATMENT RECOMMENDED:

Because of the nature and complexity of the bank composition treatment will not stop erosion. Some treatments, however, may slow erosion caused by creek undercutting. Possibly armoring the slide toe with rock or other engineering structures is a treatment that would work here.

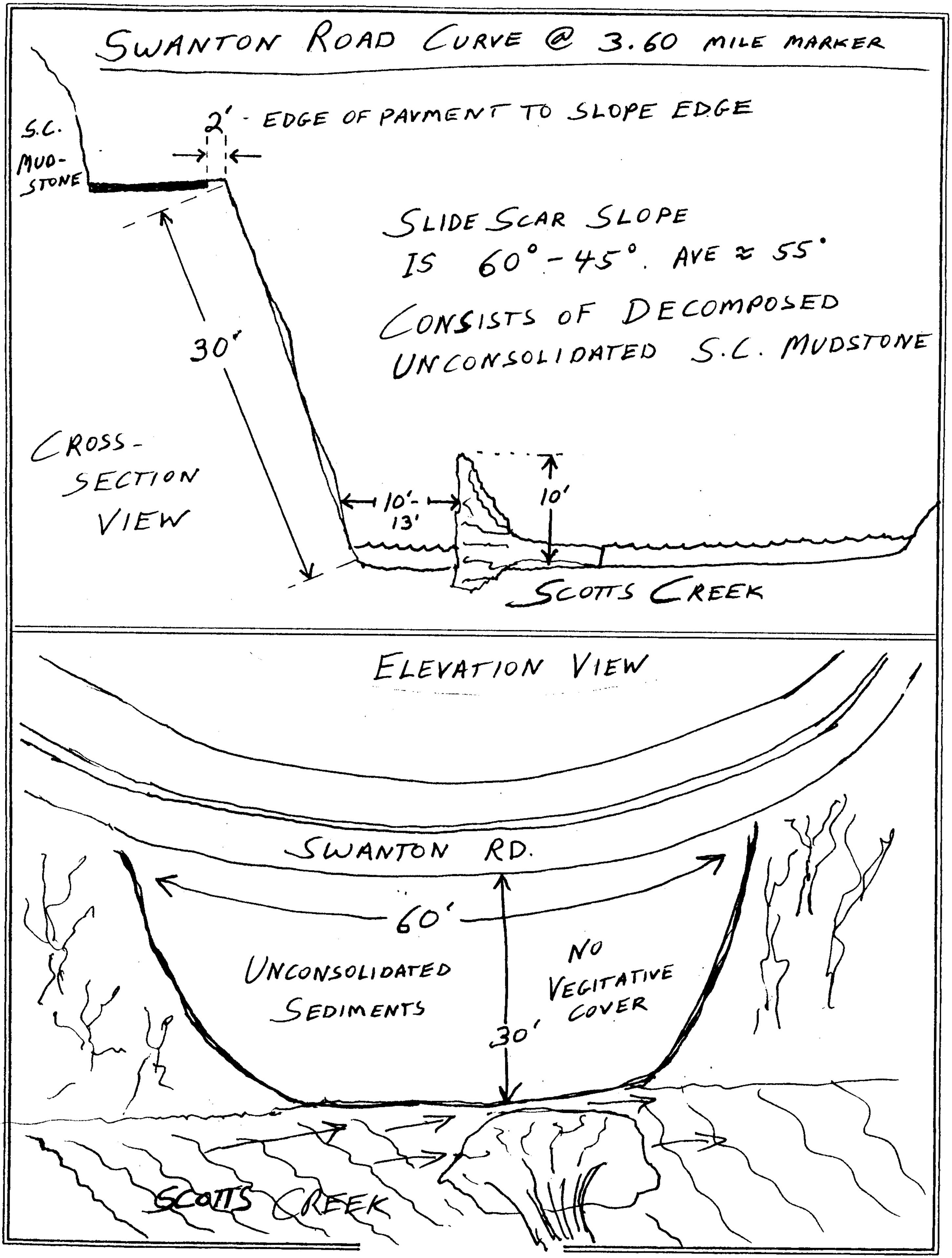
SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC6
DATE	February 2000
PREPARED BY	J. M. Rowley
SITE NAME	Swanton sharp turn @3.6 mile marker
SITE LOCATION	Site is on south west side of Swanton Road on slope below sharp curve, just before 3.6 mile marker. Approx. 3.59 miles.
YEAR/HISTORY	February 2000. No previous known history.
NATURE OF MATERIAL	
SOIL	Unconsolidated Santa Cruz Mudstone, silty clay, alluvial deposits.
BEDROCK	None exposed, Santa Cruz Mudstone exposed on road cut.
VEGETATION TYPE	None on bank. Adjacent is riparian.
DEPOSIT TYPE	Surface slump
SIZE/DIMENSIONS	30' long x 60' wide x 4'-5' deep
ESTIMATED VOLUME	400 cubic yards
% OF VOLUME IN CREEK	100%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	On edge of Swanton Road, toe in creek. Prior to slide was @ 40° forested slope.
NOTES:	Slide reactivation and/or extremely rapid erosion at this site is a certainty! Slide was most likely triggered by the failure of an Alder Tree that uprooted when it toppled. There is high potential for deposition of 1,200 - 2,000 cubic yards of clay, silt, sand and road material from this site. There is a very high likelyhood that Swanton Road will be lost at this site unless major mitigation/repair work is done. There is great potential for long lasting, in-stream salmonid habitat enhancement at this site engineered in conjunction with road repair and protection.

TREATMENT RECOMMENDED:

Because of the need for longevity of repair to this site, rock armouring (potentially in conjunction with gabion wall) with keyed in Redwood logs for salmonid habitat enhancement would be the best solution for treatment of this site.



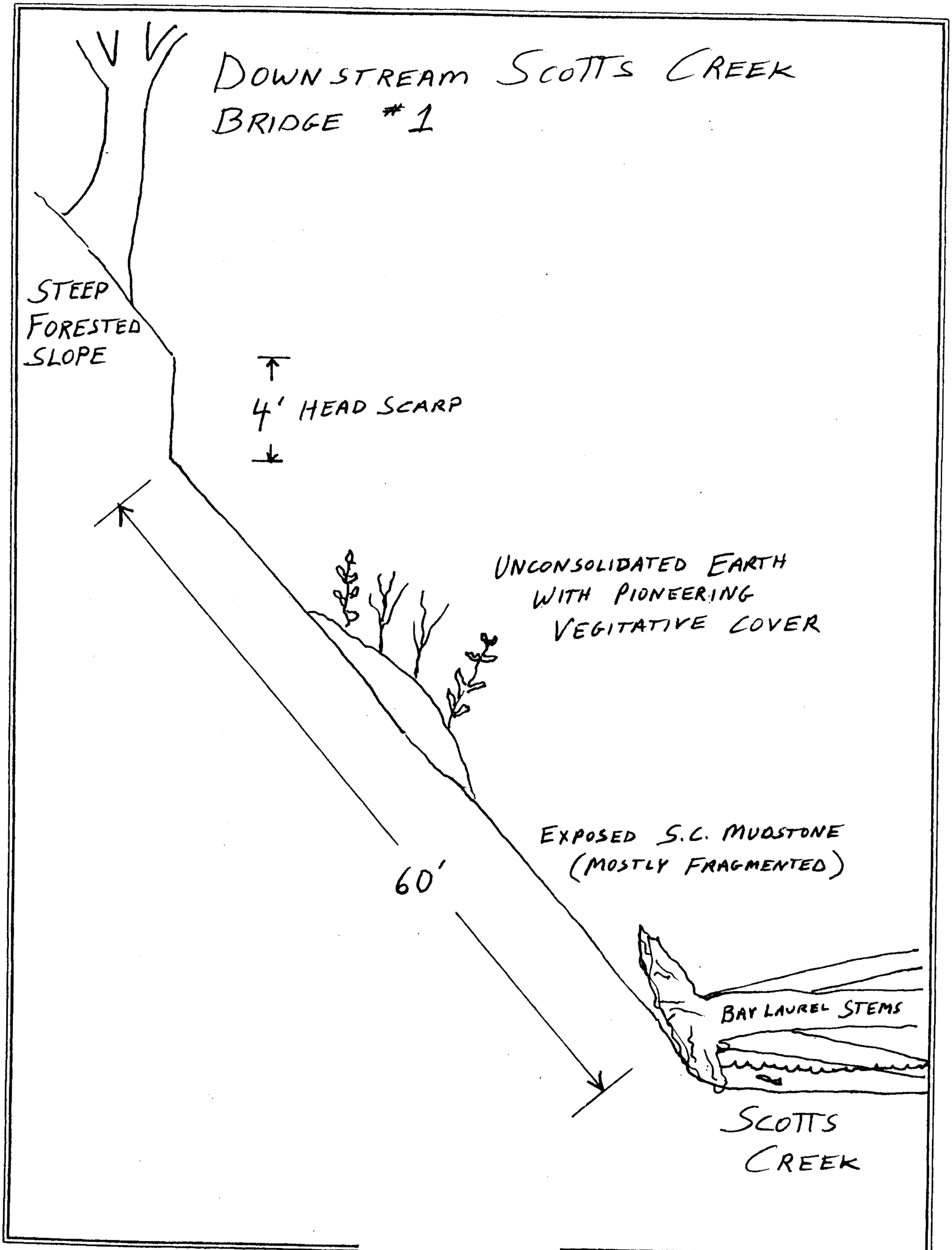
SLIDE DIAGRAM

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC7
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Bottom of Gionnoni Hill
SITE LOCATION	368 feet downstream from Swanton Road bridge crossing of Scotts Creek. N. 37° 04.780' W. 122° 14.831'
YEAR/HISTORY	February 1997
NATURE OF MATERIAL	
SOIL	Shallow forest soil and duff <2ft thick
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	California Bay
DEPOSIT TYPE	Shallow surface failure caused by large California Bay fall.
SIZE/DIMENSIONS	60' long x 30' wide x 4' deep.
ESTIMATED VOLUME	266 cubic yards
% OF VOLUME IN CREEK	100%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Steep forest slope setting, terminates in creek. No bench, bar or flood plain occurs on west bank of creek at this location.
NOTES:	Surface material all slumped off with trees! Slide scar is nearly 100% exposed bedrock. About 5% of scar has loose material on it and this has naturally revegetated. Log jam at base of slide made up of eight, 1-2' diameter California Bay trunks well anchored by root wads. Toe of slide scar is active cut bank. Slope of slide is 45°. Headscarp is 4' vertical.

TREATMENT RECOMMENDED:



SLIDE DIAGRAM

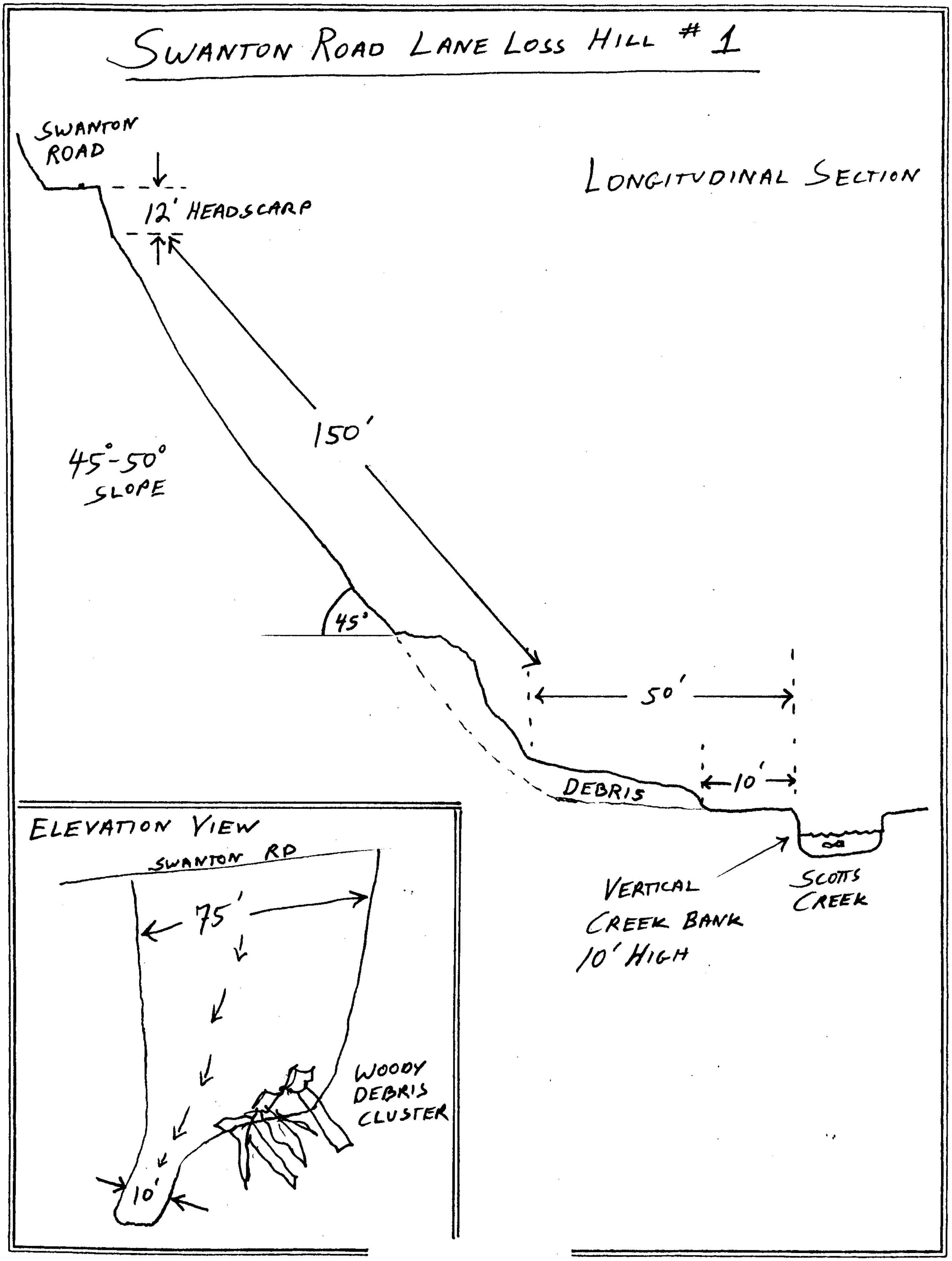
SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC8
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Swanton Rd. Lane loss #1
SITE LOCATION	.25 mi north up hill from the bridge at Scotts Creek. N 37° 04.9' W 122° 14.9
YEAR/HISTORY	February 1997. Occurs on surface of large rotated block
NATURE OF MATERIAL	
SOIL	Shallow forest soil and duff
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	California Bay, Monterey Pines, Redwoods, Oaks
DEPOSIT TYPE	Shallow surface failure and debris flow.
SIZE/DIMENSIONS	200' long x 75' wide x 6' deep. North side 4' deep s.s. 150' down slope, 50' accross near level valley bottom terrace.
ESTIMATED VOLUME	1,3898 cubic yards
% OF VOLUME IN CREEK	None. Toe of slide stops 5' short of near vertical bank top. % in creek - fines only from subsequent sheet erosion and rills.
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Head scarp at edge of Swanton Rd. is 12' vertical drop. Up slope side of road has excellent outcropping of Santa Cruz mudstone "undisturbed" but rotated by large scale ancient slide. Forestland.
NOTES:	Super saturation, steep slope and abundance of shallow rooted large trees(Bay, Buckeye, Redwood) triggered this slide. Large woody debris deposit at base of slope. 4 large Bay, 3 Redwood, and numerous Buckeye. Currently only repair/mitigation is only black plastic covering headscarp.
TREATMENT RECOMMENDED:	Consider revegetation with Redwood on lower slope, Buckeye and Toyon on Upper slope. Coordinate with

county prior to planting for assessment of road repair(if any is to be expected) which would damage new plants. Plant materials to come from local(in the watershed) gene stock.

Urge repair of road, or at least permanent stabilization of headscarp.



SLIDE DIAGRAM

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

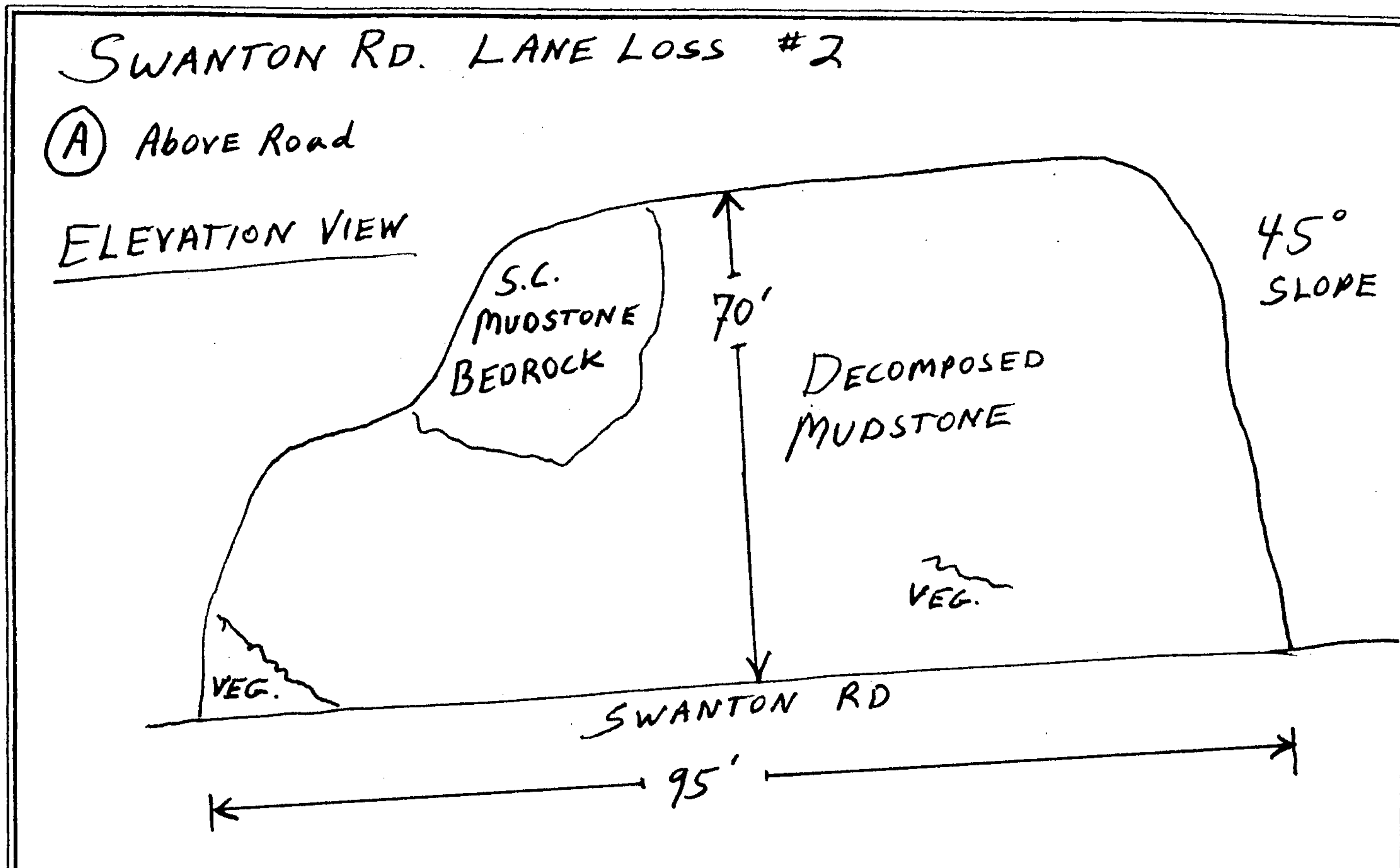
SLIDE INVENTORY

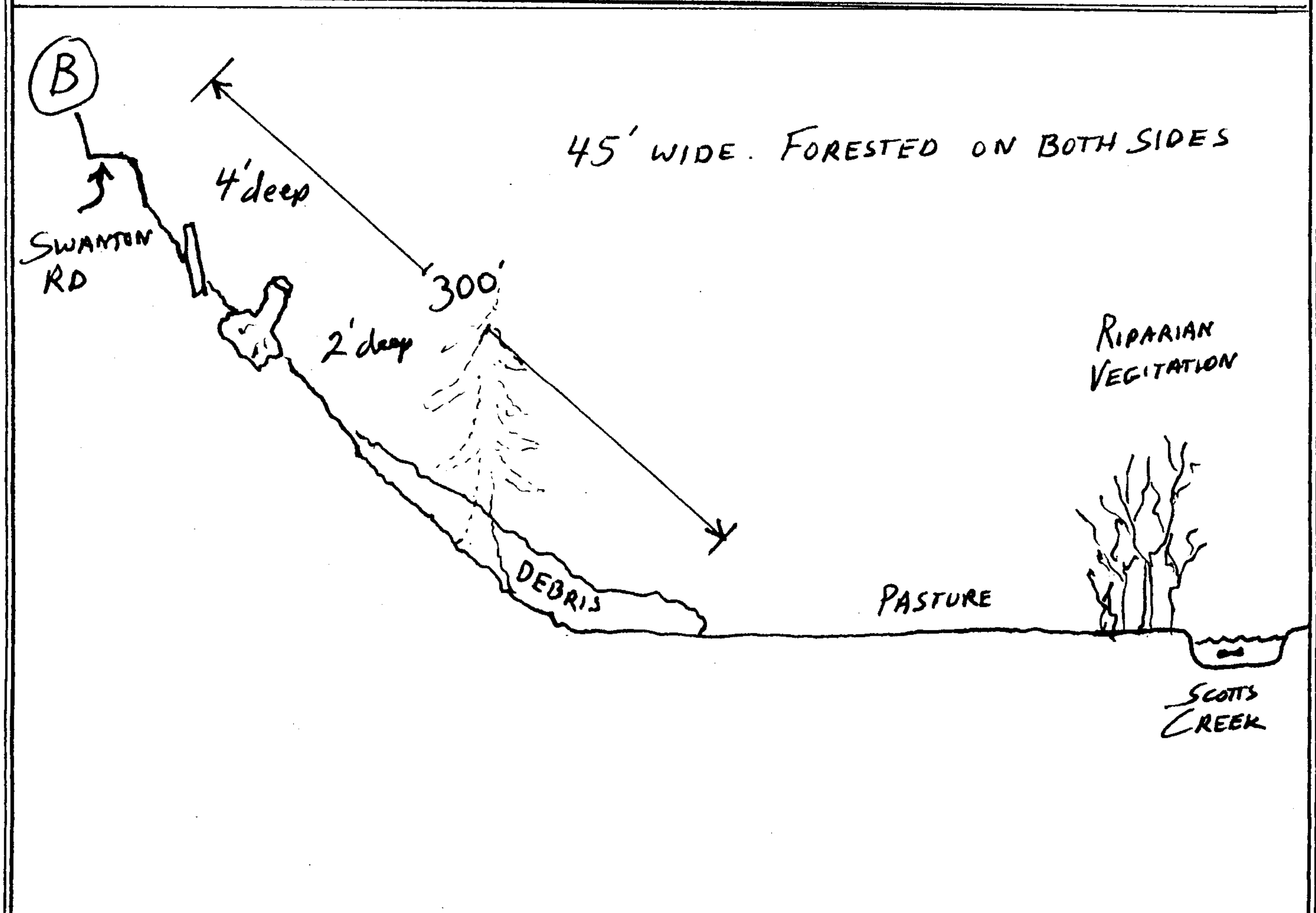
SITE NUMBER	SC9
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Swanton Rd. Lane loss #2 a) above road b) below road
SITE LOCATION	.55 mi north up hill from the bridge at Scotts Creek. N 37° 05.1 W 122° 15.0
YEAR/HISTORY	February 1997. Occurs on surface of an ancient deep rotational slump of much larger area. Seasonal significat mass wasting on a) and b) was initiated in 1995 by upper slope Redwood uprooting and sliding to bottom.
NATURE OF MATERIAL	
SOIL	Shallow <12" thick forest soil and duff
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	California Bay, Monterey Pines, Redwoods, Oaks
DEPOSIT TYPE	Shallow surface failure and debris flow.
SIZE/DIMENSIONS	a) 70' long x 95' wide 200' x 3' deep b) 300' long x 45' wide x 4' deep upper 1/2 and 2' deep lower 1/2
ESTIMATED VOLUME	a) 738 cubic yards b) 1000 cubic yards
% OF VOLUME IN CREEK	a) None. Terminates at Swanton Road. B) None. Toe is @ 250' from creek on flat pasture.
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Adjacent to Swanton Road. a) Above. Forest land. b) Below. Forest land on sides and pasture at toe.
NOTES:	a) Surface slide above Swanton Rd. Currently <5% vegetation cover. Exposed bedrock 200 sq. ft. The remainder is unconsolidated mudstone. Slope @ 45°. Head scarp - 2' vertical b) Surface slide and debris flow with 10' high near vertical head scarp taking part of Swanton Rd. prism. Good quantity of large woody debris distributed along full length of slide much of it incorporated into regolith. Vegetation covers @ 30% mostly pioneering "weed". (thistle, blackberry, some grasses)

TREATMENT RECOMMENDED:

Recommend stabilization with biotechnical techniques. Revegetate with Redwood and fir on lower slope, and smaller species(Buckeye, ceanothus, native grasses) for initial stabilization.
Buckeye and Toyon on Upper slope. Coordinate with county prior to planting for assessment of road repair(if any is to be expected) which would damage new plants. Plant materials to come from local(in the watershed) gene stock.

Urge repair of road, or at least permanent stabilization of headscarp. Encourage county to make properly engineered road repair.





SLIDE DIAGRAM

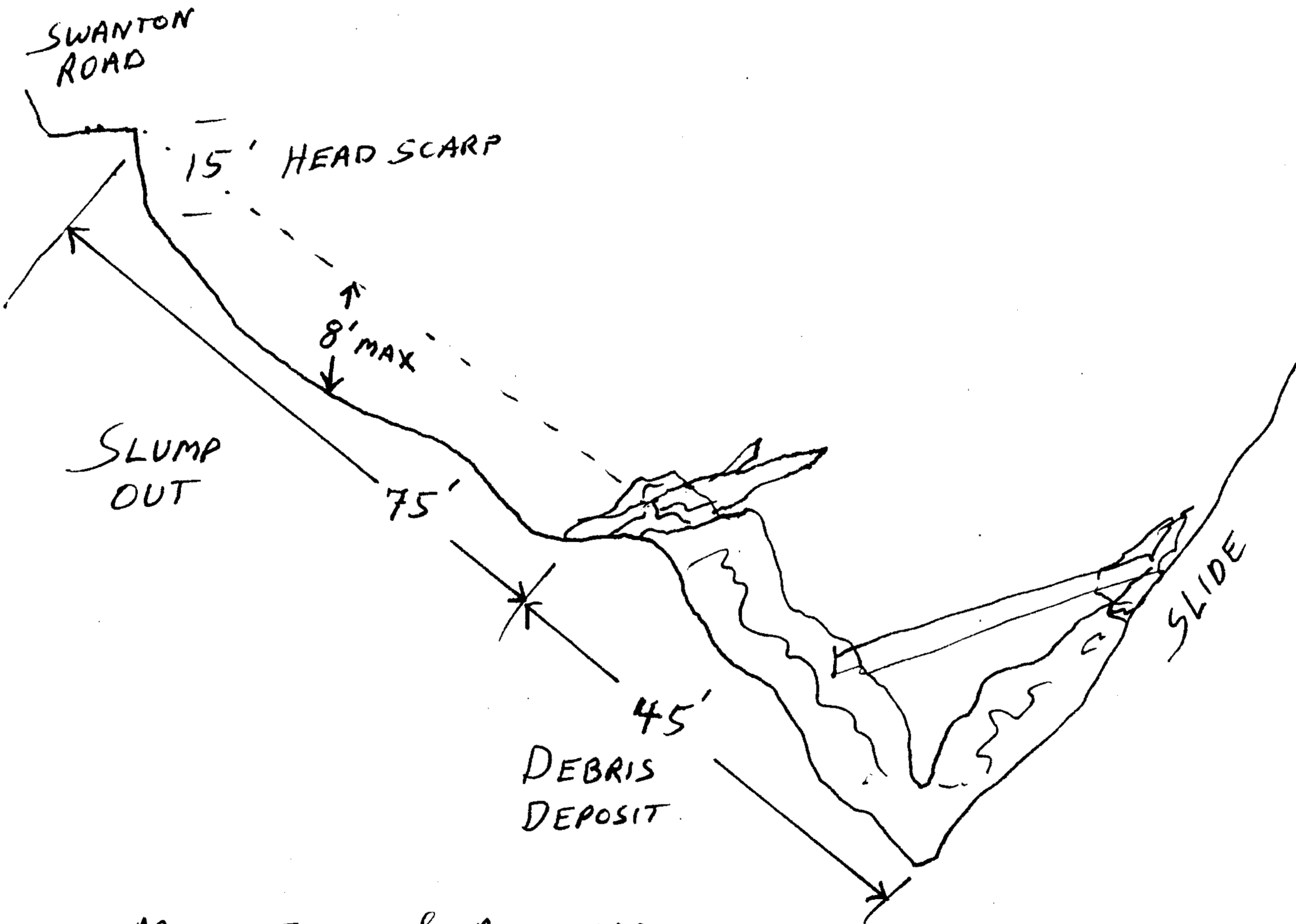
SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC10
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Swanton Rd. Lane loss #3
SITE LOCATION	.75 mi north up hill from the bridge at Scotts Creek. Toe is in dry Arroyo drainage tributary to Scotts Creek. N 37° 05.097 W 122° 15.261'
YEAR/HISTORY	February 1998.
NATURE OF MATERIAL	
SOIL	Shallow <12" thick forest soil and duff
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	Mixed upland forest of Oak, Bay, Redwood, Monterey Pine, Buckeye, Toyon etc..
DEPOSIT TYPE	Slump/semi liquefied debris flow
SIZE/DIMENSIONS	120' long x 65' wide x 4'-8' deep.
ESTIMATED VOLUME	1,733 cubic yards
% OF VOLUME IN CREEK	50%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Adjacent to Swanton Road. Head scarp is the downslpe shoulder of Swanton Road. Slide terminated at bottom of Arroyo with some material turning and flowing down the Arroyo drainage.
NOTES:	The upper 75' of slope slumped out and flowed to bottom of Arroyo. Several large trees and rootwads incorporated in the slide formed framework to stabilize slide on lower slope. Head scarp is 15' high and near vertical.
TREATMENT RECOMMENDED:	None - Head scarp is protected by black plastic. Slide is 80% vegetated(all volunteer) Recommend properly engineered repair to road.

SWANTON ROAD LANE LOSS #3

CROSS SECTION VIEW



MANY TREES & ROOT WADS
HUNG UP IN BOTTOM OF ARROYO

CLASS 3
DRAINAGE

SLIDE DIAGRAM

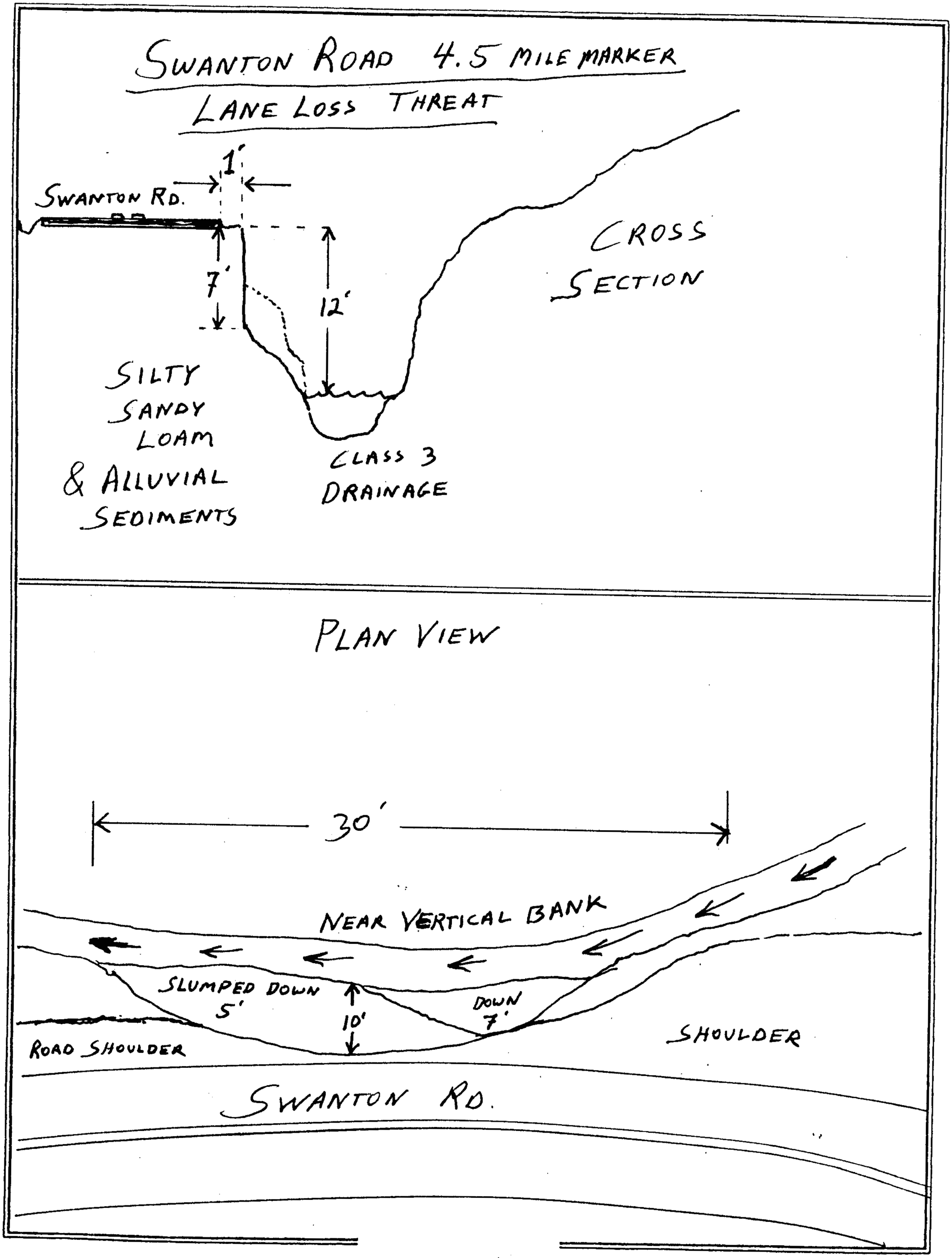
SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	SC11
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Swanton Rd. 4.5 mile marker
SITE LOCATION	Approximately 40' N.W. on Swanton Rd. from mailbox @ 482 Swanton ~300' from bridge over Scotts Creek.
YEAR/HISTORY	February 1998.
NATURE OF MATERIAL	
SOIL	Dark forest soils and alluvial
BEDROCK	none
VEGETATION TYPE	Riparian perennials
DEPOSIT TYPE	Slump
SIZE/DIMENSIONS	12' long x 30' wide x 4' deep.
ESTIMATED VOLUME	40 cubic yards
% OF VOLUME IN CREEK	60%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	On shoulder of Swanton Rd., uphill from the bridge over Scotts Creek
NOTES:	This slumping into the high velocity class 3(winter) is very l likely to continue at a rapid rate and threatens Swanton Rd. It is estimated that another 100-200 cubic yards of fine sediments will erode into the creek from this source.

TREATMENT RECOMMENDED:

Biotechnical and/or rock armoring should be used to protect Swanton Road and to keep fine sediments from degrading salmonid habitat.



SLIDE DIAGRAM

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	MC1
DATE	December 1999
PREPARED BY	C. Wilson
SITE NAME	Mill Creek road closure slide
SITE LOCATION	Approximately 1/3 mile up road on Mill Creek
YEAR/HISTORY	Winter 1997-1998
NATURE OF MATERIAL	
SOIL	Forest soil
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	Sparse re-colonization at base, none at top. Adjacent Douglas Fir, Redwood, Bay, Oaks and forest perennials .
DEPOSIT TYPE	Debris flow in existing draw
SIZE/DIMENSIONS	520' long x 20' wide x 10' deep. Mid terrace is 40' wide, mud debris flowed at base, prior to reaching creek to a width of 65' square.
ESTIMATED VOLUME	3,852 cubic yards
% OF VOLUME IN CREEK	70%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Abandoned road terrace and residential access road at base of slope. Toe of slide in Mill Creek.
NOTES:	Debris flow was apparently caused by concentration of water from ridge top. This site is cut to bedrock only in top portion. Terraces of an abandoned logging road and the residential access road helped to keep much debris from reaching the creek, but mud continued to flow into Mill Creek from this slide throughout the month of February 1998.

TREATMENT RECOMMENDED:

Redistribution of runoff. If it is necessary to channelize water collected on ridge line then convey and dissipate on gentle slopes or convey all the way to creek in inpervious medium (pipe). Re-vegetation of slope with soil stabilizing native plants. (blackberries, ceanothus, buckeyes, willows)

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	MC2
DATE	December 1999
PREPARED BY	C. Wilson
SITE NAME	Mill Creek picnic site
SITE LOCATION	Approximately 3/4 mile up road on Mill Creek
YEAR/HISTORY	Winter 1997-1998
NATURE OF MATERIAL	
SOIL	Forest soil
BEDROCK	Santa Cruz Mudstone
VEGETATION TYPE	Sparse sucker re-colonization at base of downed Redwoods, slide bare. Adjacent Redwood, Bay, Oaks and forest perennials .
DEPOSIT TYPE	Rotational slump flow with delivery from channel fill.
SIZE/DIMENSIONS	50' long x 35' wide x 15' deep upper portion, 50' long x 45' wide x 15' deep at base.
ESTIMATED VOLUME	2,083 cubic yards
% OF VOLUME IN CREEK	75%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Fire road/trail at base of slope. Toe of slide in Mill Creek.
NOTES:	Debris flow was caused by concentration of water from ridge top flowing into existing channel. Saturated channel fill vegetated with heavy mature trees caused partial clearing of channel. Terrace of fire road/trail caught some material before it reached creek. This site is cut to bedrock only in top, left portion and so will continue to unload sediment into creek. Gulleys of about 1-1/2' start about midway on slide and cut through outer edges of slope. A large berm of channel fill/forest duff, vegetated with a clump(8 trees)of Redwoods rests within right side of slide. This clump of trees has started to lean indicating soil movement. This block of soil represents

about 500 cubic yards of material that will definitely reach Mill Creek.

TREATMENT RECOMMENDED:

Treatment for this site would include unloading of slope by thinning or removal of redwood clump. Re-vegetation of slope and biotechnical gulley treatment are also recommended.

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

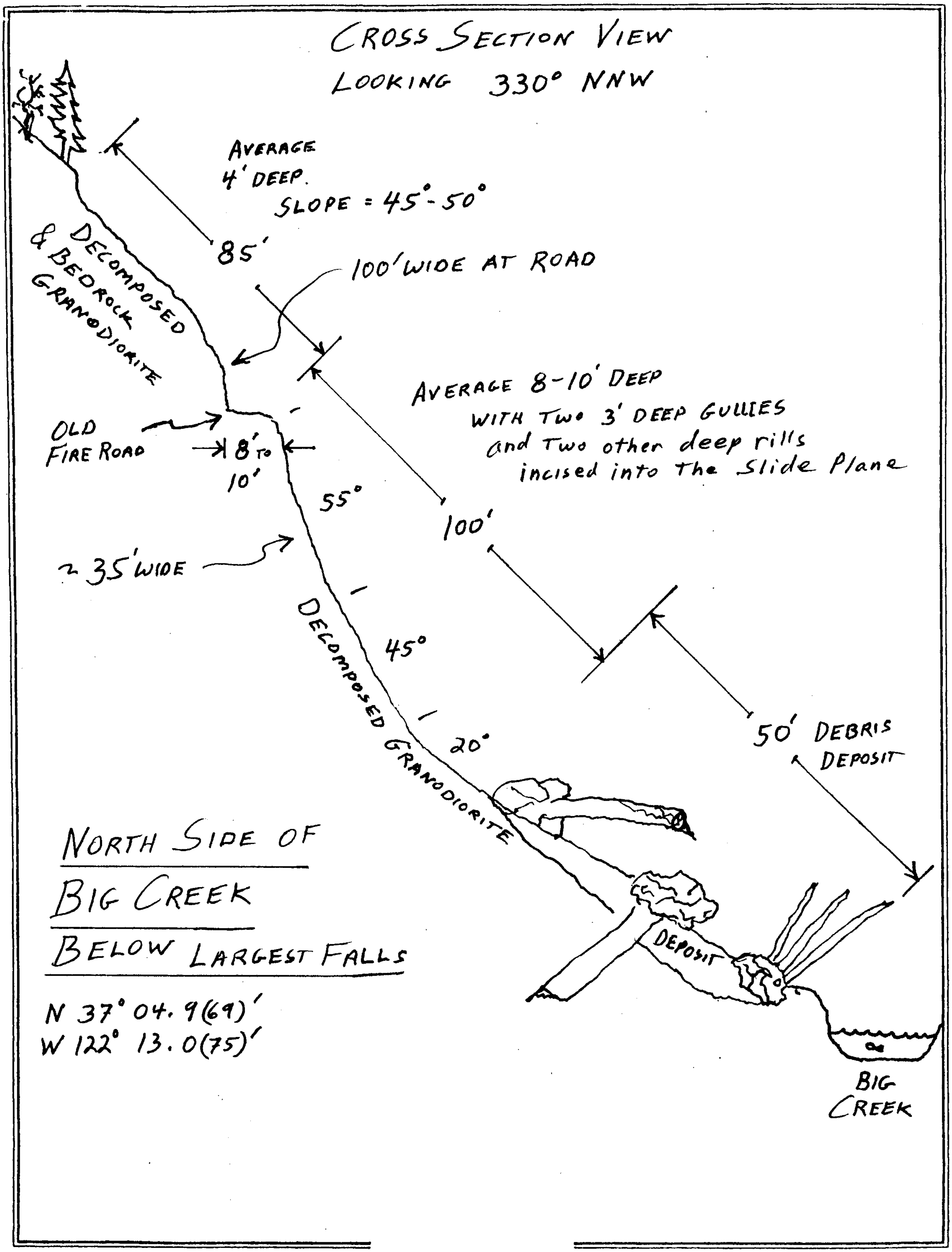
SLIDE INVENTORY

SITE NUMBER	BC1
DATE	October 1999
PREPARED BY	J. M. Rowley
SITE NAME	Big Creek below falls
SITE LOCATION	N. 37° 04.979(69)' W. 122° 13.049(75)' ~ 300 yards down stream of largest falls on Big Creek
YEAR/HISTORY	Winter 1997-1998
NATURE OF MATERIAL	
SOIL	Forest soil and weathered quartz diorite.
BEDROCK	Granite and weathered quartz diorite
VEGETATION TYPE	Little vegetation on slope at this time. Debris at toe consists of redwoods and douglas fir
DEPOSIT TYPE	Thick regolith or weathered quartz diorite rock slide or flow.
SIZE/DIMENSIONS	85' long x 35' wide x 8'-10' deep to terrace, 100' long x 100' wide x 10' deep below terrace, 15' long x 150' wide x 8' deep of debris at base.
ESTIMATED VOLUME	1,471cubic yards down to debris. 670 cubic yards of debris at base of slide.
% OF VOLUME IN CREEK	50%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Adjacent to creek. Small fire road traverses slope approximately 85 feet down slide. Slide toe is in Big Creek. Waterfall approximately 45 yards upstream.
NOTES:	This shallow slide/flow occurred because of the steepness of the natural slope in combination with the degree of decomposition of the quartz diorite and the supersaturated conditions caused by the El Nino storms of 1997-98. This slope could have gone as a slide or a flow as weathered quartz diorite can do either depending on its saturation. Deep gullys of 2'-3' run the length of the slope and testify to the high rate of fine sediments from this site

into the creek. This site and all the surrounding hillside will continue to fail in this manner.

TREATMENT RECOMMENDED:

Treatment recommendations for this site are not feasible as the whole canyon is made up of the same material and will probably fail as this site did. Dangerous and expensive work on this site could stabilize the slide scar and accelerate re-vegetation. The presence of a much larger, similar slide above Big Creek (w/ very different access) has triggered the idea for an all encompassing solution. Several members of the council have discussed the construction of sediment catchment basins in the creek which would trap large quantities of moving sediment after it enters the creek from these slide events. The basins would be built below potential landslide area. These basins would also provide pools for fish during low water months.

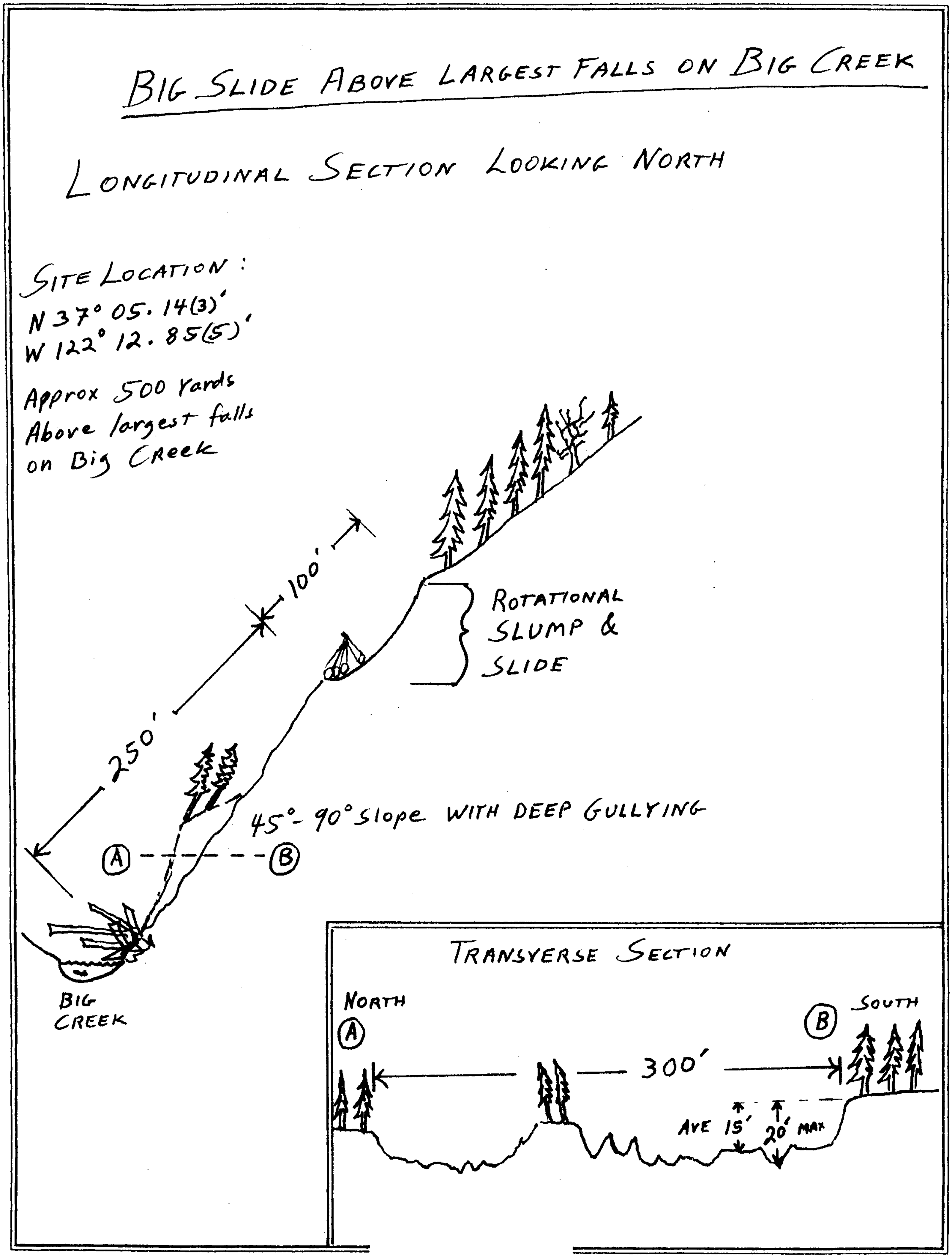


SLIDE DIAGRAM

SCOTTS CREEK WATERSHED COUNCIL
125 SWANTON ROAD~DAVENPORT CA 95017

SLIDE INVENTORY

SITE NUMBER	BC2
DATE	December 1999
PREPARED BY	J. M. Rowley
SITE NAME	Big slide above Big Creek Falls
SITE LOCATION	N. 37° 05.14(3)' W. 122° 12.85(5)' Downslope bearing 276° magnetic
YEAR/HISTORY	Winter 1997-1998
NATURE OF MATERIAL	
SOIL	Forest soil and weathered quartz diorite
BEDROCK	Granite
VEGETATION TYPE	Sparse recolonization.
DEPOSIT TYPE	Liquification style surface slide and rotational slump
SIZE/DIMENSIONS	350' long x 185' wide at top, 220' wide in middle, 300' wide at bottom x 20' deep.
ESTIMATED VOLUME	20,000 cubic yards
% OF VOLUME IN CREEK	75%
PROXIMITY TO OTHER FEATURE & WHAT TYPE	Toe in Big Creek. Very steeply sloped redwood forest.
NOTES:	Thick deposit of easily eroded decomposed granite remains on steep hillside. This sand and silt is unconsolidated and rapidly eroding. Deep gullying is occurring. The toe of the rotational slump at the bottom of the upper 100' of the slide will not impede unconsolidated material from the upper slide from reaching the creek. There is large potential for huge volume of fine sediment eroding into the creek from this slide scar.
TREATMENT RECOMMENDED:	A sediment catch basin may be the only practical solution to keeping fine sediments out of the creek. There is significant potential for more slides of this type and scale to occur along this reach of Big Creek.



SLIDE DIAGRAM